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THE PSYCHOMOTOR PERFORMANCE OF MEN AND WOMEN WEARING TWO TYPES OF BODY ARMOR

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This study was conducted to determine the effects of load-carrying equipment (LCE) and two types of fragmentation protective armor vests, Standard B Fragmentation Protective Body Armor (STD B) and the Personnel Armor System for Ground Troops (PASGT), on body flexibility, rate of movement, psychomotor coordination, manual dexterity, and effort exerted for task performance. Twelve men and 12 women, outfitted in utilities, performed the battery of 16 tasks under each of the following clothing conditions: utilities alone, STD B armor, PASGT armor, LCE, STD B armor + LCE, and PASGT armor + LCE. In general, performance levels

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were highest when the utilities were worn without any additional items and lowest when the STD B vest was worn in conjunction with the LCE. The STD B armor impaired certain aspects of psychomotor performance, particularly body flexibility, to a greater extent than the PASGT vest did. The collar and shoulder designs seemed to be the critical features responsible for the superior performance achieved with the PASGT vest. After the data had been transformed to remove effects accounted for by differences in the basic capabilities of men and women, two tasks which required arm movements were found to be significantly affected by the sex variable. The women's performance of these movements was impaired relative to the men's because of the excessive length of the armor across the women's shoulders.

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THE PSYCHOMOTOR PERFORMANCE OF MEN AND WOMEN WEARING TWO TYPES OF BODY ARMOR

INTRODUCTION

Body armor is used by military ground troops for protection against the fragmentation threat posed by conventional munitions and the higher-velocity, lower-mass, improved conventional munitions. Armor vests used by ground troops cover the upper torso and neck areas. The primary consideration in designing these vests is to maximize protection of vital body areas while minimizing interference with troop performance. A program to develop a new armor vest to replace those presently being used by ground troops has recently been completed. Some of the goals of this effort were to reduce casualties due to conventional munitions by at least 25% and those due to improved conventional munitions by at least 40% relative to those sustained with the present armor vests. The study reported here was one of those undertaken to evaluate the impact of the new vest on troop performance.

Independent Variables

The purpose of the present study was to evaluate the effects on the psychomotor performance of men and women of wearing the new armor vest vs. the effects of wearing the present vest for Army ground troops. These items were worn over utility shirts and trousers and both with and without load-carrying equipment. Therefore, the effects of adding either armor or load-carrying equipment or both to the body could also be assessed. The armor vest currently available in the Army's inventory is referred to as the Standard B Fragmentation Protective Body Armor. The material in this vest is ballistic nylon. The new vest is part of the Personnel Armor System for Ground Troops. The ballistic filler in this new vest is composed of layers of Kevlar. The vests differ not only in the levels of protection afforded, but also in design characteristics. They are of approximately equal weight.

Dependent Variables

The dependent variables on which the effects of body armor and load-carrying equipment were determined were divided into five categories: (1) body flexibility, (2) rate of movement, (3) psychomotor coordination, (4) manual dexterity, and (5) effort exerted for task performance. These measures were part of a larger list proposed by Siegel, Bulinkis, Hatton, and Crain[1] to be used in evaluations of pressure suits and other flight apparel. Tests in all five categories were employed by Bensel and Lockhart[2] in a previous study of the effects of body armor on performance.

[1] Siegel, A.I., Bulinkis, J., Hatton, R., & Crain, K. **A technique for the evaluation of operator performance in pressure suits and other flight apparel** (Tech. Rep. NAMC–ACEL–435). Philadelphia: Naval Air Material Center, 1960.

[2] Bensel, C.K. & Lockhart, J.M. **The effects of body armor and load-carrying equipment on psychomotor performance** (Tech. Rep. 75–92–CEMEL). Natick, MA: US Army Natick Development Center, May 1975.

The flexibility tasks evolved principally from an investigation by Saul and Jaffe.[3] The purpose of their study was to develop and analyze quantitative techniques for measuring movement interference due to clothing and equipment. The tasks were used to measure the limits of movement of various parts of the body, including the head and neck, arm and shoulder, trunk and waist, and leg and hip. They also involved movement of segments in the frontal, the sagittal, and the transverse planes of the body.[4] The flexibility tasks in the present experiment were: (1) Ventral-Dorsal Head Flexion, (2) Head Rotation, (3) Standing Trunk Flexion, (4) Sitting Trunk Flexion, (5) Upper Arm Abduction, (6) Upper Arm Forward Extension, (7) Upper Arm Backward Extension, (8) Upper Leg Abduction, (9) Upper Leg Forward Extension, and (10) Upper Leg Flexion. Standing and Sitting Trunk Flexion involved bending of the upper trunk at the waist in the body's sagittal plane. Upper Arm and Upper Leg Abduction required movement in the frontal plane, while Forward and Backward Upper Arm Extension, Forward Upper Leg Extension, and Leg Flexion were movements in the body's sagittal plane.

Bensel and Lockhart (reference 2) included all of these flexibility tasks, with the exception of those involving leg movements, in a study to assess the effects of two types of body armor on the psychomotor performance of men. The armor was worn over cold-wet clothing consisting of cold weather underwear, a wool shirt, a field jacket, and field trousers. The armor used was the Standard 8 vest and another fragmentation protective vest with a ballistic filler of nylon cloth, the Conventional Munitions and Improved Conventional Munitions vest. The latter is of the same design as the new armor vest. However, the vests differ in the ballistic filler material used and in weight, with the new vest being slightly heavier. Bensel and Lockhart (reference 2) found that performance on all flexibility tasks, with the exception of Upper Arm Backward Extension, was significantly affected by the experimental conditions. In general, performance levels were highest when the cold-wet clothing was worn without any additional equipment and lowest when the Standard B armor was worn in conjunction with load-carrying equipment. However, more specifically, the impact on performance of adding either armor or load-carrying equipment or both to the cold weather uniform varied as a function of the body parts involved in the task. For example, the head movements were only minimally affected by the load-carrying equipment, even when it was worn in conjunction with armor. The determining factor was the presence or absence of armor. For Upper Arm Abduction and Forward Extension, there was a worsening in performance when either type of armor or load-carrying equipment was worn and additional performance decrements when load-carrying equipment was used in conjunction with body armor.

In addition to the 10 flexibility tasks included in the performance battery for the present study, two rate of movement tasks, the Figure-8 Run and Duck and the Ball-Pipe Tests, were used. These were chosen primarily to measure the speed with which subjects could accomplish a given movement or series of movements. The Figure-8 Run and Duck Test involved both

[3]Saul, E.V. & Jaffe, J. **The effects of clothing on gross motor performance** (Tech. Rep. EP--12). Natick, MA: US Army Quartermaster Research and Development Center, June 1955.

[4]Roebuck, J.A. A system of notation and measurement for space suit mobility evaluation. **Human Factors**, 1968, **10**, 79--94.

bending at the waist to pass under a horizontal bar and running. McGinnis[5] found that the performance level of men on this task was lowered significantly when body armor was added to the utility shirt and trousers. However, no differences in scores were obtained between the two types of armor which he tested, 48-plate and 135-plate, titanium nylon vests. Bensel and Lockhart (reference 2) also found that performance on the Figure-8 Run and Duck was impaired when body armor was worn and that the scores for each type of armor which they tested were essentially equal.

The other rate of movement task, the Ball-Pipe Test, required that the arm and hand be repeatedly and rapidly raised above shoulder height. Bensel and Lockhart (reference 2) had subjects perform this task continuously for 5 min.; the task duration in the present study was 3 min. They found that the poorest performance occurred when load-carrying equipment was worn with the Standard B armor. McGinnis (reference 5) also found that the worst scores for 5-min. trials were obtained when load-carrying equipment was used with body armor.

The psychomotor tasks used in the present study, the Railwalk and the Pursuit Rotor, have been included in other performance batteries. Kiess and Lockhart[6] used the former in a study of the effects of weight on the torso. They attached lead weights of either 0.0, 2.27, 4.54, or 6.82 kg (0.0, 5.0, 10.0, or 15.0 lb, respectively) to a webbing harness worn on the chest and waist. Weight on the torso had a significant effect on the Railwalk with optimum performance associated with weights of 2.27 and 4.54 kg. Using men who had had no practice on the task, Bensel and Lockhart (reference 2) found Railwalk performance to be unaffected by the use of armor vests or load-carrying equipment.

The other psychomotor coordination task included in the present performance battery, the Pursuit Rotor, required that the subject use a stylus to track a target which moved in a circle. The stylus was grasped in the hand, and tracking was effected by movement of the arm and shoulder. This test has been used to assess the effects of cold weather clothing on psychomotor performance.[7,8] In general, time on target decreased as the number of clothing layers worn was increased.

[5] McGinnis, J.M. **Some effects of body armor on motor performance** (Tech. Rep. 73–13–PR). Natick, MA: US Army Natick Laboratories, October 1972.

[6] Kiess, H.O. & Lockhart, J.M. **Upper torso weight and components of psychomotor performance.** Unpublished manuscript, US Army Natick Laboratories, 1967.

[7] Bensel, C.K., Bryan, L.P., & Mellian, S.A. **The psychomotor performance of women in cold weather clothing** (Tech. Rep. NATICK/TR–77/031). Natick, MA: US Army Natick Research and Development Command, October 1977.

[8] Lockhart, J.M. & Bensel, C.K. **The effects of layers of cold weather clothing and type of liner on the psychomotor performance of men** (Tech. Rep. NATICK/TR–77/018). Natick, MA: US Army Natick Research and Development Command, June 1977.

The fourth category of tasks used in the present study was manual dexterity. This was represented by the Bennett Hand Tool Dexterity Test, which involved simultaneous use of both hands, and the O'Connor Finger Dexterity Test, which was done with one hand. Therefore, possible differential effects of the armor vests and load-carrying equipment on a one- vs. a two-handed task could be assessed. The O'Connor Finger Dexterity Test was used in the Lockhart and Bensel (reference 8) and the Bensel et al. (reference 7) studies and was not affected by the cold weather clothing worn.

In the present experiment, heart rate was employed as the measure of effort exerted under the various conditions. It was recorded at selected intervals during the performance of the task battery in order to determine whether higher rates would be associated with some conditions than with others. Haisman and Goldman,[9] exposing men wearing body armor over the combat tropical uniform to both hot-wet (35.0°C D.B./30.3°C W.B., 95.0°F D.B./86.5°F W.B.) and hot-dry (48.9°C D.B./28.4°C W.B., 120.0°F D.B./83.1°F W.B.) climates, obtained higher heart rates for the Standard B armor than for the Conventional Munitions and Improved Conventional Munitions vest. The men walked on a level treadmill at 1.12 m/sec (2.5 mi/hr) for two, 50-min. periods with an intervening 15-min. rest. The weight of a backpack was manipulated so that the total weight carried was identical and both types of armor covered almost identical surface areas. They maintained that such design features of the Conventional Munitions and Improved Conventional Munitions armor as its ability to move with the subject and greater spaces or gaps for air penetration with motion had physiologically beneficial effects.

In addition to the quantitative measures of performance on the task battery, a questionnaire was employed to obtain subjective reports regarding the armor and load-carrying equipment worn. Participants were asked to indicate those tasks in the battery in which the clothing worn interfered with performance and to rate the impact of various clothing design characteristics on performance. The questionnaire used here was similar to the one devised by Bensel and Lockhart (reference 2) for their armor study and included scales of bipolar adjectives, such as comfortable-uncomfortable, heavy-light, and like-dislike. In responding to the questionnaire, the subjects in that study emphasized the importance of flexibility as a design characteristic affecting performance and rated armor shoulder and collar flexibility as being moderately to considerably important in impairing their scores. The bulk and weight of those conditions involving load-carrying equipment were also rated as problem areas by the subjects.

METHOD

Subjects

The subjects were 12 men and 12 women who volunteered to participate in this study. The men ranged in age from 18 to 24 years with the mean age being 22 years. The mean age of the women was 25 years and they ranged in age from 19 to 36 years. Body measurements were obtained for all subjects. Descriptive statistics for the measures are presented in Table 1 and information regarding the measuring techniques employed is presented in Appendix A.

[9] Haisman, M.F. & Goldman, R.F. Physiological evaluations of armored vests in hot-wet and hot-dry climates. Ergonomics, 1974, 17, 1–12.

Table 1

Selected Body Dimensions of the Study Sample
(12 Men and 12 Women)

Measure	Mean	s.d.	Range	Min	Max
Stature (cm)					
Men	175.2	7.0	27.8	160.4	188.2
Women	165.3	7.4	26.4	147.8	174.2
Waist Front Length (cm)					
Men	39.3	2.5	6.5	37.0	43.5
Women	35.6	3.7	11.0	30.5	38.8
Waist Back Length (cm)					
Men	44.2	3.4	9.0	41.5	50.5
Women	39.7	6.2	23.0	23.0	46.0
Shoulder Length (cm)					
Men	15.7	1.4	5.5	13.0	18.5
Women	14.2	1.4	4.2	12.0	16.2
Sleeve Inseam (cm)					
Men	50.4	3.0	9.7	44.5	54.2
Women	47.3	3.1	11.7	41.0	52.7
Sleeve Outseam (cm)					
Men	59.5	3.6	12.5	52.0	64.5
Women	55.6	3.2	11.0	51.0	62.0
Sleeve Length (cm)					
Men	87.7	5.1	17.5	77.5	95.0
Women	80.0	3.5	11.0	74.0	85.0
Crotch Height (cm)					
Men	77.4	3.9	13.3	72.2	85.5
Women	77.2	3.9	13.7	68.9	82.6
Waist Height (cm)					
Men	105.8	4.8	18.1	96.2	114.3
Women	101.9	4.5	15.9	91.8	107.7
Neck Circum. (cm)					
Men	39.0	2.2	6.0	36.0	42.0
Women	33.1	1.5	5.9	31.5	37.4

Table 1 (Continued)

Selected Body Dimensions of the Study Sample
(12 Men and 12 Women)

Measure	Mean	s.d.	Range	Min	Max
Shoulder Circum. (cm)					
Men	119.5	8.2	27.4	107.7	135.1
Women	106.2	4.8	16.6	97.4	114.0
Arm Scye Circum. (cm)					
Men	45.6	3.9	16.5	37.5	54.0
Women	38.4	1.8	5.2	35.6	40.8
Chest Circum. at Scye (cm)					
Men	99.1	5.4	14.8	93.2	108.0
Women	86.2	4.0	13.5	80.4	93.9
Chest Circum. (cm)					
Men	95.0	6.1	20.0	88.0	108.0
Women	88.1	4.8	14.5	80.5	95.0
Waist Circum. (cm)					
Men	83.1	10.3	31.0	72.0	103.0
Women	71.9	4.2	12.5	65.5	78.0
Hip Circum. (cm)					
Men	100.3	7.5	24.8	89.2	114.0
Women	96.6	3.7	9.3	91.5	100.8
Interscye Breadth (cm)					
Men	39.6	3.1	9.3	35.5	44.8
Women	35.3	2.7	7.5	31.5	39.0
Natural Waist Circum. (cm)					
Men	—	—	—	—	—
Women	70.0	4.0	13.3	64.5	77.8
Weight (kg)					
Men	77.4	13.0	45.0	58.4	103.4
Women	62.1	4.7	15.5	54.6	70.1

Clothing, Armor, and Equipment

Throughout the testing phase of the study, the men wore the men's combat utility shirt and trousers (Coat and Trousers, Hot Weather, Men's Combat) and the women wore the women's utility shirt and trousers (Shirt and Slacks, Utility, Women's, Cotton, OG—107). All the items are made of cotton-poplin, wind resistant cloth which has a weight of 193.3 to 227.2 g/m^2 (5.7 to 6.7 oz/yd^2). Gym shoes and T-shirts were also worn throughout the study. No handwear or headwear was used.

The two types of armor vests used were the Standard B Fragmentation Protective Body Armor with 3/4 Collar (STD B) and the Personnel Armor System for Ground Troops (PASGT) vest. Information regarding the physical characteristics of the four sizes of both vests is presented in Table 2.

The STD B armor vest consists of a ballistic filler made of 12 plies of ballistic nylon cloth. The filler is sealed in a waterproof, vinyl envelope. The outer shell and the inner lining of the vest are of lightweight nylon cloth. The vest has a zipper front and elastic laces on both sides. The laces allow some adjustment for proper fit. Incorporated into the outer shell of the vest are two pockets and two grenade hangers. The vest also has a 3/4, stand-up collar made of 12 plies of ballistic nylon. The STD B armor is designed to provide fragmentation protection against grenades, mortars, and shell fragments.

The PASGT vest is made of 13 plies of ballistic filler. The filler is water-repellent treated Kevlar with a weight of 474.8 g/m^2 (14 oz/yd^2). The inner and the outer shells are water-repellent treated ballistic nylon with a weight of 271.3 g/m^2 (8 oz/yd^2). The layer which makes up the inner cover of the vest is olive green. The outer cover is in camouflage colors and design. The ballistic filler in the back of the vest is divided into four sections. The three upper sections slide over each other and the lower section during body movement. The front closure is formed with hook and pile fastener tape. The side overlaps are made flexible through the use of sewn-in, elastic webbing which is 3.81 cm (1.5 in.) wide. The vest also has a fragmentation protective, 3/4 stand-up collar, articulating shoulder pads with elastic webbing and snaps, two front pockets, two grenade hangers, and rifle butt patches at the shoulders. The ballistic materials in the PASGT vest provide increased protection from fragmenting munitions compared to that provided by the STD B vest.

Load-carrying equipment (LCE) was also used in the present study. It consisted of the following fighting load components of the All-Purpose Lightweight Individual Carrying Equipment (ALICE):

Individual Equipment Belt

Individual Equipment Belt Suspenders

Two Small Arms Ammunition Cases

Intrenching Tool Carrier

Table 2

Physical Characteristics of STD B and PASGT Vests

Measure	STD B Sm.	STD B Med.	STD B Lge.	STD B X-Lge.	PASGT Sm.	PASGT Med.	PASGT Lge.	PASGT X-Lge.
Neck Opening Circum. (cm)	57.1	60.4	65.2	67.8	51.6	54.4	56.8	59.3
Armhole Opening Circum. (cm)	47.5	52.8	53.3	54.2	59.6	64.3	65.3	68.7
Chest Inside Circum. (cm)	94.1	100.1	109.5	116.2	99.4	109.9	124.2	130.2
Waist Inside Circum. (cm)	101.1	106.9	123.6	131.8	98.9	111.2	121.1	130.2
Front Inside Length (cm)	42.8	43.6	46.0	47.4	41.4	42.0	45.8	46.1
Back Inside Length (cm)	56.7	58.0	61.1	63.8	58.2	59.8	60.3	61.6
Shoulder Length (cm)	16.3	16.3	17.3	17.3	14.2	14.2	14.2	14.2
Cross Back (cm)	42.2	48.2	53.1	55.7	35.4	38.3	43.1	46.7
Collar Height (cm)	8.0	8.0	8.0	8.0	7.0	7.0	7.0	7.0
Shoulder Thickness (cm)	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0
Chest Thickness (cm)	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0
Back Thickness (cm)	1.2	1.2	1.2	1.2	1.0	1.0	1.0	1.0
Collar Thickness (cm)	1.2	1.2	1.2	1.2	.5	.5	.5	.5
Weight (kg)	3.90	4.22	4.52	5.06	3.71	4.02	4.53	4.95
Sizing by Chest Circum. (cm)	≤92.7	94.0-102.9	104.1-113.0	≥114.3	≤94.0-	>94.0-≤104.1	>104.1 <114.3	≥114.3

Intrenching Tool

Canteen Cover

Canteen

Field First Aid Dressing Case

The canteen was filled with water and each ammunition case was loaded with weights totalling 1.64 kg (3.61 lb) to simulate the weight and bulk of 30 rounds of M16 ammunition. The first aid dressing case was worn on the left front suspender. The ammunition cases were placed on each side of the belt buckle. In the front, the suspenders were secured to eyelets on each ammunition case. In the back, the suspenders were hooked to belt eyelets on each side of the two center eyelets. The canteen and carrier were on the right side of the belt next to an ammunition case and the intrenching tool and carrier were on the left side next to the other ammunition case. The total weight of the LCE was 6.76 kg (14.9 lb).

Combinations of the LCE, the body armor, and the utilities comprised the six clothing conditions tested in the present study. Pictures of the conditions are presented in Appendix B. The conditions were:

1. Men's combat utility shirt and trousers or women's utility shirt and trousers (Utilities)

2. Utilities and the STD B armor vest (Utilities + STD B)

3. Utilities and the PASGT vest (Utilities + PASGT)

4. Utilities and the load-carrying equipment (Utilities + LCE)

5. Utilities, the STD B vest, and the LCE (Utilities + STD B + LCE)

6. Utilities, the PASGT vest, and the LCE (Utilities + PASGT + LCE)

Tasks

Sixteen tasks were used to assess the performance of the subjects in this experiment. A goniometer was used on eight tasks to measure the angular displacement of various parts of the body. The goniometer is an instrument consisting of a rotatable pendulum mounted in front of a moveable 360° scale. Both the scale and the pendulum are mounted on a thin block which is attached to a long strap. Accurate use of the goniometer demands that the scale remain in an almost vertical plane so that the pendulum can rotate freely to the vertical. As used in this study, the goniometer was strapped in a vertical position to a part of the body and set to zero by turning the moveable scale until the 0° mark coincided with the pendulum. The subjects were then instructed to move their bodies in a certain fashion and, when the maximum amplitude of movement was reached, the degrees of arc through which the body part had passed were read directly from the point on the scale with which the pendulum was then aligned.

The first 10 tasks comprising the performance battery were used to measure the amplitude of movement at various body joints. The remaining tasks involved such a flexibility component, as well as rate of movement, manual dexterity, and psychomotor coordination factors. The tasks were administered in a standard manner and in the same order for all subjects. There were four trials on 12 of the tasks and one trial on each of the remaining four tasks. The tasks are briefly described below in order of presentation. Additional information regarding the battery and directions for administering the tests are presented in Appendix C.

Task 1. **Ventral-Dorsal Head Flexion.**[10] The seated subjects moved their heads as far forward as possible and the goniometer, positioned on the right side of the head, was set to zero. They then moved their heads as far back as possible and the angular displacement was read, in degrees, from the goniometer.

Task 2. **Head Rotation** (reference 10). The goniometer was placed on top of the head. The subjects bent at the waist so that their heads and chests were parallel to the floor. They rotated their heads as far left as possible, and the goniometer was set to zero. They then rotated their heads as far right as possible and the angular displacement was read, in degrees, from the goniometer.

Task 3. **Standing Trunk Flexion** (reference 10). The subjects did a toe-touch while keeping their knees straight. The task was used to measure how far the subjects could bend toward their toes, with higher scores indicating greater distances.

Task 4. **Sitting Trunk Flexion** (reference 10). The subjects sat on a bench with their legs straight out in front of them and touched their toes while keeping their knees straight. The task was used to measure how far the subjects could bend toward their toes, with lower scores indicating greater distances.

Task 5. **Upper Arm Abduction.**[11] The goniometer was placed on the right arm above the elbow. The subjects stood with their bodies touching a corner of a wall and the goniometer was set to zero. Both arms were raised sideward and upward as far as possible and the angular displacement was read, in degrees, from the goniometer.

Task 6. **Upper Arm Forward Extension** (reference 10). The goniometer was placed on the right arm above the elbow. The subjects stood erect with their arms against their sides and their elbows stiff. The goniometer was set to zero. The right arm was then raised as far forward and up as possible with the elbow being kept stiff. The angular displacement was read, in degrees, from the goniometer.

[10] Dusek, E. R. & Teichner, W. H. **The reliability and intercorrelations of eight tests of body flexion** (Tech. Rep. EP–31). Natick, MA: US Army Quartermaster Research and Development Center, May 1956.

[11] Dusek, E. R. **Encumbrance of arctic clothing** (Tech. Rep. EP–85). Natick, MA: US Army Quartermaster Research and Engineering Center, April 1958.

Task 7. **Upper Arm Backward Extension** (reference 3). The goniometer was placed on the right arm above the elbow. The subjects stood erect with their backs against a wall, their right shoulders and arms just past the edge of a doorway, their arms at their sides, and their elbows stiff. They rotated their right arms until the palm was facing out and the thumb was pointed dorsally. The goniometer was set to zero. The right arm was then raised backward as far as possible, with the elbow being kept stiff, and the angular displacement was read, in degrees, from the goniometer.

Task 8. **Upper Leg Abduction** (reference 3). The goniometer was placed on the right leg above the knee. The subjects stood erect with feet together and facing an upright support about one foot in front of them which they grasped with both hands. The goniometer was set to zero. The subjects raised their right legs sideward and up as far as possible while keeping the leg straight and the angular displacement, in degrees, was read from the goniometer.

Task 9. **Upper Leg Forward Extension** (reference 8). The subjects stood erect with their backs against a wall and their feet together. The goniometer was placed on their right leg above the knee and set to zero. Supporting themselves with the left hand on the back of a chair positioned to the left side, the subjects raised their right legs forward while keeping their knees stiff, and angular displacement was read, in degrees, from the goniometer.

Task 10. **Upper Leg Flexion** (reference 3). The subjects stood erect with their backs against a wall and their feet together. The goniometer was placed on the right leg above the knee and set to zero. Supporting themselves with the left hand on the back of a chair positioned to the left side, the subjects raised their right upper legs as far as possible while letting their right knees bend freely. The maximum angular displacement was read, in degrees, from the goniometer.

Task 11. **Pursuit Rotor.**[12] This was a test of psychomotor coordination involving the arm and the shoulder. The subject was required to keep the tip of a stylus, which was held in the preferred hand, in contact with a disc which was 1.25 cm (.49 in.) in diameter and was embedded in the surface of a turntable. The stylus tip was .4 cm (.16 in.) in diameter. The disc was located 2.0 cm (.79 in.) from the edge of the turntable which was 26.0 cm (10.24 in.) in diameter and rotated at a speed of 60 rev/min. The score was the total time on target, read to the nearest .01 sec, during a 30-sec trial.

Task 12. **Figure-8 Run and Duck.**[13] This test was used as a measure of rate of movement. In this task, the subjects were required to alter their body positions while moving forward rapidly in a Figure-8 pattern around two uprights placed 213.36 cm (84.0 in.) apart and ducking under a crossbar adjusted to waist height. This was done six times without stopping, and the score was the total time required, read to the nearest .01 sec.

[12] Melton, A. W. (Ed.) **Apparatus tests** (AAF Aviation Psychology Program Research Report No. 4). Washington, DC: Government Printing Office, 1947.

[13] Fleishman, E. A. **The Structure and Measurement of Physical Fitness.** Englewood, NJ: Prentice-Hall, 1964.

Task 13. O'Connor Finger Dexterity Test.[14] In this test of manual dexterity, the subject was required to put three pins in each of 20 holes using only one hand. The pins were 2.5 cm (.98 in.) long and .1 cm (.04 in.) in diameter. The holes were .5 cm (.20 in.) in diameter. The score was the time required, read to the nearest .01 sec, to complete the task.

Task 14. Bennett Hand Tool Dexterity.[15] This was a test of manual dexterity used to measure proficiency in the use of wrenches and screwdrivers. Two open-end wrenches, one adjustable wrench, and a screwdriver were used to loosen, relocate, and tighten six bolt, nut, and washer combinations of three different sizes. The score was the time required, read to the nearest .01 sec, to complete the task.

Task 15. Railwalk.[16] This was a test of psychomotor coordination involving several sensorimotor groups. A rail, 365 cm (143.70 in.) long and 1.90 cm (.75 in.) thick, was marked at intervals of 1.0 cm (.39 in.). While grasping their hands behind their backs, the subjects were to walk the rail in heel to toe fashion. The score was the distance from the start of the rail, where the heel was initially positioned, to the toe of the last foot that remained on the rail when balance was lost.

Task 16. Ball-Pipe Test (reference 11). This was a measure of rate of movement. A pipe, 2.54 cm (1.0 in.) in internal diameter and 50.80 cm (20.0 in.) long, was attached vertically to a wall with the top of the pipe set 14.50 cm (5.7 in.) above the top of each subject's head. A net was located below the pipe approximately 91.44 cm (36.0 in.) from the floor. The number of times a steel ball, 2.22 cm (.87 in.) in diameter, was dropped through the pipe was recorded every 30 sec during 3 min. of continuous performance. The subject was instructed to drop the ball into the pipe with preferred hand and to catch it as it came out of the pipe with the same hand. However, failure to catch the ball was not deducted from the score.

In addition to employing this task battery to obtain quantitative performance data, a questionnaire was administered to the subjects in order to elicit their subjective opinions regarding those tasks comprising the battery which were most affected by the body armor and the LCE worn. They were also asked to rank and to rate the extent to which a number of design characteristics may have aided or impaired their performances. A complete copy of the questionnaire is presented in Appendix D.

Heart rate was recorded at four intervals during performance of the task battery. A silver cup electrode for monitoring heart rate was affixed to the ventral surface of each lower arm and connected to a wide-band, a.c. preamplifier (Grass Instruments, Model 7P3), the output of which was recorded on a polygraph (Grass Instruments, Model 7).

[14] Hines, M. & O'Connor, J. A measure of finger dexterity. **Journal of Personnel Research**, 1926, **4**, 379–382.

[15] Bennett, G. K. **Hand Tool Dexterity Test Manual of Directions.** New York: Psychological Corporation, 1965.

[16] Dusek, E. R. **Standardization of tests of gross motor performance** (Tech. Rep. EP–81). Natick, MA: US Army Quartermaster Research and Engineering Center, January 1958.

Procedure

Before testing began, measurements of selected body dimensions were obtained for all subjects (Table 1) and they were issued the appropriately-sized utilities, body armor, and LCE. The selection of the particular size of body armor to be tried on by a subject was made according to chest circumference. The sizing of the PASGT and the STD B armor as a function of chest circumference is presented in Table 2. Each subject donned utilities, armor, and LCE, and the fit of these items was assessed by an experienced clothing designer who determined if other sizes should be tried in order to achieve a more acceptable fit. No alterations were made on any of the items. When the best fit had been achieved, the designer rated the fit of both types of armor vest on each of the subjects.

Prior to testing, the subjects also received practice on four tasks in the battery: the Railwalk, the Pursuit Rotor, the O'Connor Finger Dexterity, and the Bennett Hand Tool Dexterity Tests. The practice phase extended over three days and included two sessions per day. At each session, the subjects received five trials on each of the above tasks with the exception of the Pursuit Rotor, on which they received 10 trials. During this time, the subjects were also familiarized with all tasks in the battery, the questionnaire, and the general procedure to be followed during the experimental sessions. The men wore shirts and trousers and the women wore blouses and slacks. All subjects wore gym shoes and the temperature in the testing area was maintained at 18.3° to 21.2°C (65° to 70°F).

During the experimental sessions, a period of increased physical activity, the test chamber temperature was lowered to 15.6°C (60°F) for the comfort of the subjects. Each subject participated at the same time each day, either in the morning or in the afternoon, for two consecutive days. At each session, the subject performed all tasks in the battery under three of the six clothing conditions. Before beginning the first task in the battery, the subject was outfitted in gym shoes, T-shirt, utility shirt and trousers, and the remaining armor or LCE for the condition. After heart rate had been recorded for 60 sec (reading 1), the subject was instructed in and performed the first task, Ventral-Dorsal Head Flexion. After completing the Figure-8 Run and Duck Test, the subject stood while heart rate was again recorded for 60 sec (reading 2) and was then given a rest of approximately 5 min. During this rest, the subject completed a part of the questionnaire, Section I, Questions 1 and 2, Movements. In responding to the questionnaire, the subject was instructed to analyze the clothing and equipment being worn and to indicate how these items may have affected performance on the flexibility tasks.

After the rest, heart rate was again recorded for 60 sec (reading 3) and the subject performed the remaining tasks in the battery. After the final task, the Ball-Pipe Test, the fourth heart rate record was obtained (reading 4) and the subject completed the questionnaire. This procedure was repeated for the subsequent clothing conditions. Approximately 40 min. were required to complete all the tasks in the battery.

For the experimental sessions, the 12 men and 12 women were divided into six groups of two men and two women each. Each group received a different sequence of exposure to the clothing conditions. The six sequences, presented in Table 3, were based upon a Random

Table 3

Order in Which the Six Clothing Conditions Were Presented to Each Subject

Sequence No.	Subject No. Men	Subject No. Women	Clothing Condition: Utilities	Utilities +STD B	Utilities +PASGT	Utilities +LCE	Utilities +STD B +LCE	Utilities +PASGT +LCE
1	1,7	1,7	6	2	5	4	1	3
2	2,8	2,8	1	5	2	3	6	4
3	3,9	3,9	3	1	6	2	4	5
4	4,10	4,10	4	6	1	5	3	2
5	5,11	5,11	5	4	3	1	2	6
6	5,12	6,12	2	3	4	6	5	1

Square. Of the four subjects in a group, one man and one woman participated in the morning and the others in the afternoon. All men completed the experiment before testing of the women was initiated.

After completion of all data collection, two separate forms of the analysis of variance were performed on each of the 16 tasks in the battery. The first form of analysis of variance, the raw score analysis, compared the effects of all six clothing conditions on performance. The raw data used in the analysis of Tasks 1 through 11 and Task 15 of the battery were the mean scores obtained by summing over the four trials on each task. On the remaining tasks, the raw data were the scores obtained on the single trial administered. For the second form of analysis, the percentage score analysis, the raw scores obtained by each subject for all clothing conditions, excluding the utilities alone, were converted to percentages of the subject's score for utilities. Percentage scores greater than 100% indicate a performance level superior to that achieved when only utilities were worn, while those less than 100% indicate a performance level inferior to that achieved with the utilities. The analyses of variance were according to the following designs:

1. Raw Score Analysis: Subjects (1–12) by clothing conditions (Utilities, Utilities + STD B, Utilities + PASGT, Utilities + LCE, Utilities + STD B + LCE, Utilities + PASGT + LCE) within sex (Men, Women)

2. Percentage Score Analysis: Subjects (1–12) by clothing conditions (Utilities + STD B, Utilities + PASGT, Utilities + LCE, Utilities + STD B + LCE, Utilities + PASGT + LCE) within sex (Men, Women)

Because of equipment difficulties, the data for only nine men and nine women were available for analysis on the Pursuit Rotor Test and the data for 11 men and 11 women were availabale on the Ball-Pipe Test.

One analysis of variance was performed on the heart rate measure. The raw data were the second and the fourth readings taken. The design of this analysis was: Subjects (1–12) by clothing conditions (Utilities, Utilities + STD B, Utilities + PASGT, Utilities + LCE, Utilities + STD B + LCE, Utilities + PASGT + LCE), by reading (Reading 2, Reading 4) within sex (Men, Women).

For the questionnaire, the responses of the men and the women to each question under each clothing condition were compiled and summarized. The Kolmogorov-Smirnov two-sample test[17] was performed on the questions comprising Sections II and III of the questionnaire in order to determine whether or not responses varied significantly as a function of the sex of the respondents. In addition, the Friedman two-way analysis of variance by ranks (reference 17) was applied to the data of Section III in order to test for significant differences among responses as a function of clothing conditions.

[17] Siegel, S. **Nonparametric Statistics for the Behavioral Sciences**. New York: McGraw-Hill Book Company, 1956.

RESULTS

Body Dimension and Armor Fit Data

Selected body dimensions of the subjects wearing each armor size are presented in Table 4. It was found that the best fit in each type of vest, as determined by an experienced clothing designer, was achieved by following the sizing rules based upon chest circumference (Table 2). Each subject wore the same size in both types of armor. It can be seen that small, medium, and large vests were required to accommodate the 12 men, while all the women wore the small vests. The numbers appearing in parentheses in Table 4 under the means of the men's body dimensions are percentile values which indicate where the means of the subjects fell on distributions of the dimensions of 6682 Army men.[18] With the exception of the waist circumference measurement, the percentiles associated with the women's dimensions were obtained from the body measurements of 1331 Army women. The percentile for waist circumference is based upon data from 255 Army women.[19] In those instances in which comparable data on the Army population were not available, percentiles are not presented.

As is noted in Table 4, t-tests were performed to determine whether or not the mean body dimensions of the women, all of whom wore small vests, were significantly different from the dimensions of the seven men who also wore small vests. The results of the significant t-tests are presented in Table 4. It was found that the mean neck, arm scye, chest, and waist circumferences of the seven men were significantly greater than those of the women, as were the mean interscye breadth and the mean weight of the men.

While the subjects were wearing utilities and the best-fitting size in each type of vest, the vests were rated by an experienced clothing designer with regard to various length factors. The factors were rated as being too long, too short, or acceptable, and the amounts by which the vests were too long or too short were also measured. In order to provide an objective basis for the ratings, body references or landmarks were chosen and the relationships between the vest and these reference points were assessed. It should be recognized that the establishment of the body references was somewhat arbitrary. The ratings as a function of sex, armor vest type, and vest size are presented in Table 5.

Waist front length was judged to be acceptable if the front bottom edge of the vest ended at the level of the omphalion. The STD B vest extended below this level on all subjects with the exception of one man, and the PASGT vest was rated as being too long on all the men and women. The mean amount by which the vests extended below the omphalion was greater for the PASGT than for the STD B vest. With either type of vest, the mean distance

[18] White, R.M. & Churchill, E. **The body size of soldiers: US Army anthropometry — 1966** (Tech. Rep. 72–51–CE). Natick, MA: US army Natick Laboratories, December 1971.

[19] Churchill, E., Churchill, T., McConville, J.T., & White, R.M. **Anthropometry of women of the US Army — 1977: Report No. 2 — The basic univariate statistics** (Tech. Rep. NATICK/TR–77/024). Natick, MA: US Army Natick Research and Development Command, June 1977.

Table 4

Mean Dimensions of Subjects for Each Armor Size

Measure	Women Small (n=12)	Armor Size Men Small (n=7)	Medium (n=3)	Large (n=2)
Stature (cm)	165.23 (64.67)	171.64 (33.28)	178.27 (72.05)	183.05 (90.02)
Waist Front Lgth. (cm)	35.77	37.89	39.80	43.25
Waist Back Lgth. (cm)	39.72	43.41 (33.56)	42.63 (25.50)	49.00 (86.89)
Shoulder Lgth. (cm)	14.16 (21.00)	15.30 (30.67)	15.20 (28.86)	17.70 (77.00)
Neck Circum. (cm)	33.11 (69.75)	38.21 (67.17)	39.20 (81.22)	41.40 (96.54)
Arm Scye Circum. (cm)	38.45 (67.71)	44.00 (45.88)	45.87 (69.00)	50.50 (95.38)
Chest Circum. at Scye (cm)	86.15 (56.85)	95.50	101.57	108.00
Chest Circum. (cm)	88.13 (51.56)	91.10 (42.50)	97.00 (71.86)	105.95 (95.08)
Waist Circum. (cm)	71.88 (33.00)	75.79 (32.65)	87.83 (83.38)	101.50 (97.96)
Hip Circum. (cm)	96.57 (58.60)	95.30 (60.94)	103.67 (91.93)	113.00 (>99)
Interscye Breadth (cm)	35.32 (13.40)	38.70 (45.25)	38.67 (44.88)	43.85 (93.33)
Weight (kg)	62.10 (62.09)	69.04 (42.45)	81.73 (82.60)	100.47 (98.46)

Note: t-tests were performed on each measure to compare the mean dimensions of the women with the mean dimensions of the men wearing a size small armor vest. Those tests which resulted in significant differences between the means are as follows:

Neck Circumference: $t(17)=5.92$, $p<.01$
Arm Scye Circumference: $t(17)=4.80$, $p<.01$
Chest Circumference at Scye: $t(17)=5.43$, $p<.01$
Waist Circumference: $t(17)=2.27$, $p<.05$
Interscye Breadth: $t(17)=2.65$, $p<.02$
Weight: $t(17)=2.84$, $p<.02$

Table 5

Fit Ratings of Armor Vests

Factor	Armor	Sex	Size	Rating: Too Long n	Too Long Mean Amt. (cm)	Too Short n	Too Short Mean Amt. (cm)	Acceptable n
Waist Front Length	STD 8	Women	Small	12	8.49	0		0
		Men	Small	7	5.35	0		0
			Medium	3	3.18	0		0
			Large	1	5.08	0		1
	PASGT	Women	Small	12	12.88	0		0
		Men	Small	7	8.07	0		0
			Medium	3	7.20	0		0
			Large	2	5.72	0		0
Weist Back Length	STD 8	Women	Small	0		0		12
		Men	Small	0		0		7
			Medium	0		0		3
			Large	0		0		2
	PASGT	Women	Small	0		0		12
		Men	Small	0		0		7
			Medium	0		0		3
			Large	0		0		2
Shoulder Length	STD 8	Women	Small	12	3.29	0		0
		Men	Small	3	2.75	0		4
			Medium	1	1.91	0		2
			Large	1	3.81	0		1
	PASGT	Women	Small	10	2.38	0		2
		Men	Small	2	2.22	0		5
			Medium	0		0		3
			Large	0		0		2
Armhole Length	STD 8	Women	Small	0		0		12
		Men	Small	0		0		7
			Medium	0		0		3
			Large	0		0		2
	PASGT	Women	Small	8	2.94	0		4
		Men	Small	0		0		7
			Medium	0		0		3
			Large	0		0		2
Crossback	STD 8	Women	Small	12	3.52	0		0
		Men	Small	4	4.76	0		3
			Medium	1	6.35	0		2
			Large	1	4.45	0		1
	PASGT	Women	Small	11	2.42	0		1
		Men	Small	0		0		7
			Medium	0		0		3
			Large	0		0		2

below the omphalion was greatest for the women followed by the men who wore a size small vest (Table 5). Waist back length was found to be acceptable on all subjects regardless of which type of vest was being rated (Table 5). The criterion of acceptability applied to waist back length was that the back lower edge of the vest must not extend below the maximum protrusion of the buttocks.

Shoulder length was judged to be acceptable if the portion of the vest running along the top of the shoulder ended at the acromion. The STD B vest extended beyond this point on all of the women and on five of the men, while the shoulder length of the PASGT vest was judged to be too long on 10 of the women and on two of the men who wore small vests (Table 5). The criterion for acceptability of the armhole length was that the vest opening extend around the arm scye of the body in the underarm area. The armhole opening length of the STD B vest was found to be acceptable on all the subjects. However, the PASGT vest was too long on eight of the women. That is, the armhole opening extended down the side of the body below the arm scye. In order to rate the crossback factor, a midpoint was located between the top and the bottom of the back of the right arm scye and the relationship between the vest and this point on the arm scye was assessed. The crossback of the STD B vest was found to be too long for all the women and for six of the men, while the PASGT vest was too long for 11 of the 12 women. In these instances, the armor vest extended out beyond the arm scye.

Task Battery Data

The results of the first analysis of variance performed on each of the 16 tasks comprising the battery, the raw score analysis, are presented in Table 6. The tasks are numbered and listed in the order in which they were performed. Clothing condition had a significant effect on the data of all tasks with the exception of Upper Leg Forward Extension (Task 9) and the O'Connor Finger Dexterity Test (Task 13). The results of the Newman-Keuls multiple comparison tests performed on the means for the 14 tasks with significant clothing effects are presented in Table 7. There was a significant main effect attributable to sex on six tasks: Upper Arm Abduction and Forward Extension (Tasks 5 and 6), the Figure-B Run and Duck (Task 12), the O'Connor Finger Dexterity Test (Task 13), the Bennett Hand Tool Dexterity Test (Task 14), and the Railwalk (Task 15) (Table 6). There was a significant interaction between clothing and sex on Upper Arm Forward Extension (Task 6) and the Ball-Pipe Test (Task 16) (Table 6). The mean scores on each task as a function of clothing condition and sex are presented in Figures 1a through 16a.

The results of the second form of analysis performed on the 16 tasks, the percentage score analysis, are presented in Table 8. The scores were obtained by setting each subject's score for the utility condition equal to 100%, and expressing the remaining scores as percentages of this. Clothing condition had a significant effect on 12 of the tasks. Those tasks for which significant clothing effects were not obtained were Upper Arm Backward Extension (Task 7), Upper Leg Forward Extension and Flexion (Tasks 9 and 10), and the O'Connor Finger Dexterity Test (Task 13). The results of the Newman-Keuls multiple comparison tests performed on the mean percentage scores for the 12 tasks with significant clothing effects are presented in Table 9. The highest percentage score on both Ventral-Dorsal Head Flexion (Task 1) and the Pursuit Rotor (Task 11) was greater than 100%. This reflects the findings in the raw score analyses

Table 6

Raw Score Analyses of Variance of Task Battery Data

Source of Variance	df	Task Number 1 MS	F	2 MS	F	3 MS	F	4 MS	F
Sex (A)	1	1410.94	<1.00	1746.54	<1.00	17.56	<1.00	5.44	<1.00
Ss/A	22	1516.63		2399.45		53.06		56.59	
Clothing (C)	5	5162.05	41.13***	5435.10	25.45***	20.99	16.55***	16.51	7.79***
A x C	5	67.21	<1.00	167.05	<1.00	.85	<1.00	2.58	1.22
Ss x C/A	110	125.49		213.52		1.27		2.12	

Source of Variance	df	Task Number 5 MS	F	6 MS	F	7 MS	F	8 MS	F
Sex (A)	1	12507.62	12.68**	6778.78	14.33**	199.52	<1.00	35.25	<1.00
Ss/A	22	986.50		473.10		386.05		470.22	
Clothing (C)	5	4921.50	40.14***	3079.48	20.73***	144.90	3.95**	211.30	8.31***
A x C	5	220.50	1.80	371.68	2.50*	33.68	<1.00	32.54	1.28
Ss x C/A	110	122.59		148.58		36.66		25.42	

Source of Variance	df	Task Number 9 MS	F	10 MS	F	11[a] MS	F	12 MS	F
Sex (A)	1	30.02	<1.00	34.52	<1.00	.43	<1.00	668.70	12.94**
Ss/A	22	406.94		887.28		58.80		51.67	
Clothing (C)	5	86.54	1.90	214.48	4.14**	13.43	4.95***	163.63	32.51***
A x C	5	28.30	<1.00	35.19	<1.00	2.24	<1.00	7.98	1.58
Ss x C/A	110	45.46		51.78		2.71		5.03	

Table 6 (Continued)

Raw Score Analyses of Variance of Task Battery Data

Source of Variance	df	Task Number 13 MS	F	14 MS	F	15 MS	F	16[b] MS	F
Sex (A)	1	8135.28	20.12***	11011.70	5.91*	78762.08	5.32*	2333.52	2.48
Ss/A	22	404.30		1864.23		14791.54		942.33	
Clothing (C)	5	31.36	1.13	478.79	4.03**	11113.38	7.18***	848.84	9.75***
A x C	5	24.60	<1.00	189.04	1.59	2149.77	1.39	213.85	2.46*
Ss x C/A	110	27.83		118.78		1548.67		87.07	

***$p < .001$

**$p < .005$

*$p < .05$

[a]df = 1,16,5,5,80, respectively

[b]df = 1,20,5,5,100, respectively

Table 7

Mean Raw Score for Tasks under Each Clothing Condition

Task	Clothing Condition*					
1. Ventral-Dorsal Head Flexion (deg.)	4 138.69	1 138.48	3 119.97	6 114.35	2 107.77	5 105.60
2. Heed Rotation (deg.)	1 157.11	4 149.09	3 140.58	6 131.79	2 124.64	5 117.27
3. Standing Trunk Flexion (cm)	1 14.61	2 13.46	3 13.46	4 13.45	6 12.43	5 11.94
4. Sitting Trunk Flexion (cm)	1 2.16	4 2.93	3 3.05	2 3.48	6 4.18	5 4.38
5. Upper Arm Abduction (deg.)	1 142.22	4 125.35	3 125.02	2 116.88	6 112.28	5 99.97
6. Upper Arm Forward Exte.ision (deg.)	1 152.64	4 142.82	3 140.27	6 133.96	2 129.31	5 120.01
7. Upper Arm Backward Extension (deg.)	1 47.78	4 43.88	3 43.78	6 41.71	5 41.45	2 41.41
8. Upper Leg Abduction (deg.)	1 66.21	4 52.88	3 52.83	2 62.04	6 50.00	5 47.43
10. Upper Leg Flexion (deg.)	1 89.05	2 84.94	3 83.56	4 82.54	6 81.79	6 80.61
11. Pursuit Rotor (sec)	3 17.97	1 17.24	4 16.76	2 16.35	6 16.04	6 15.57
12. Figure-8 Run end Duck (sec)	1 30.00	3 32.33	2 32.69	4 34.38	5 36.69	6 36.62
14. Bennet Hend Tool Dexterity (sec)	1 142.26	3 145.15	2 147.14	4 148.47	6 161.76	5 154.63
15. Railweik (cm)	1 176.96	3 171.47	2 168.85	5 140.92	4 132.02	6 129.27
16. Total Bell-Pipe Score	1 141.14	3 136.18	4 136.00	2 129.73	6 128.00	6 124.09

*1 = Utilities
2 = Utilities + STD B
3 = Utilities + PASGT
4 = Utilities + LCE
6 = Utilities + STD B + LCE
6 = Utilities + PASGT + LCE

NOTE: Clothing conditions not connected by the same line ere significently different ($p < .05$).

Table 8

Percentage Score Analyses of Variance of Task Battery Data

Source of Variance	df	Task Number 1 MS	1 F	2 MS	2 F	3 MS	3 F	4 MS	4 F
Sex (A)	1	.0546	1.78	.0980	3.70	.0008	<1.00	.1794	<1.00
Ss/A	22	.0307		.0265		.0368		.3351	
Clothing (C)	4	.2157	36.76***	.1625	13.98***	.0602	9.40***	.1984	3.28*
A x C	4	.0014	<1.00	.0046	<1.00	.0047	<1.00	.0697	1.15
Ss x C/A	88	.0059		.0116		.0064		.0604	

Source of Variance	df	Task Number 5 MS	5 F	6 MS	6 F	7 MS	7 F	8 MS	8 F
Sex (A)	1	.2167	8.23**	.1203	6.16*	.1050	<1.00	.0790	2.16
Ss/A	22	.0263		.0195		.1495		.0366	
Clothing (C)	4	.1320	20.44***	.0876	12.23***	.0154	1.02	.0338	4.30*
A x C	4	.0097	1.50	.0194	2.71*	.0082	<1.00	.0052	<1.00
Ss x C/A	88	.0064		.0072		.0150		.0078	

Source of Variance	df	Task Number 9 MS	9 F	10 MS	10 F	11[a] MS	11[a] F	12 MS	12 F
Sex (A)	1	.0476	<1.00	.0116	<1.00	.0125	<1.00	.0026	1.00
Ss/A	22	.0616		.0538		.0618		.0207	
Clothing (C)	4	.0086	<1.00	.0089	1.57	.0479	4.60*	.0642	22.90***
A x C	4	.0084	<1.00	.0044	<1.00	.0066	<1.00	.0030	<1.07
Ss x C/A	88	.0126		.0057		.0104		.0028	

Table 8 (Continued)

Percentage Score Analyses of Variance of Task Battery Data

Source of Variance	df	Task Number 13 MS	13 F	14 MS	14 F	15 MS	15 F	16[b] MS	16[b] F
Sex (A)	1	.0022	<1.00	.0143	<1.00	.2698	1.31	.0643	2.95
Ss/A	22	.0343		.0286		.2058		.0218	
Clothing (C)	4	.0019	<1.00	.0131	2.69*	.2498	5.50***	.0279	6.03***
A x C	4	.0049	1.14	.0078	1.60	.0365	<1.00	.0114	2.46
Ss x C/A	88	.0042		.0049		.0454		.0046	

***$p < .001$
**$p < .01$
*$p < .05$

[a]df = 1,16,4,4,64, respectively

[b]df = 1,20,4,4,80, respectively

Table 9

Mean Percentage Score for Tasks under Each Clothing Condition

Task	Clothing Condition*				
1. Ventral-Dorsal Head Flexion	4 101.00	3 87.25	6 83.50	2 78.75	5 77.33
2. Head Rotation	4 94.92	3 89.50	6 83.67	2 79.08	5 74.12
3. Stending Trunk Flexion	4 92.12	2 91.83	3 91.08	6 84.46	5 81.17
4. Sitting Trunk Flexion	4 90.21	2 86.21	3 83.21	6 72.17	5 69.21
5. Upper Arm Abduction	3 87.92	4 87.92	2 81.38	6 79.12	5 70.00
6. Upper Arm Forwerd Extension	4 93.92	3 92.12	6 88.08	2 85.08	5 78.71
8. Upper Leg Abduction	3 94.29	4 94.25	2 92.54	6 90.08	5 85.33
11. Pursuit Rotor	3 105.00	4 98.28	2 97.33	6 93.56	5 91.61
12. Figure-8 Run end Duck	3 93.17	2 92.54	4 87.67	6 82.67	5 82.38
14. Bennett Hand Tool Dexterity	3 98.25	2 97.38	4 96.21	6 94.17	5 92.54
15. Railwalk	3 98.17	2 97.04	5 86.17	4 78.96	6 75.79
16. Total Ball-Pipe Score	3 96.82	4 95.77	2 91.91	6 90.86	5 88.18

*2 = Utilities + STD 8
3 = Utilities + PASGT
4 = Utilities + LCE
5 = Utilities + STD 8 + LCE
6 = Utilities + PASGT + LCE

Note: Clothing conditions not connected by the same line are significantly different ($p < .05$).

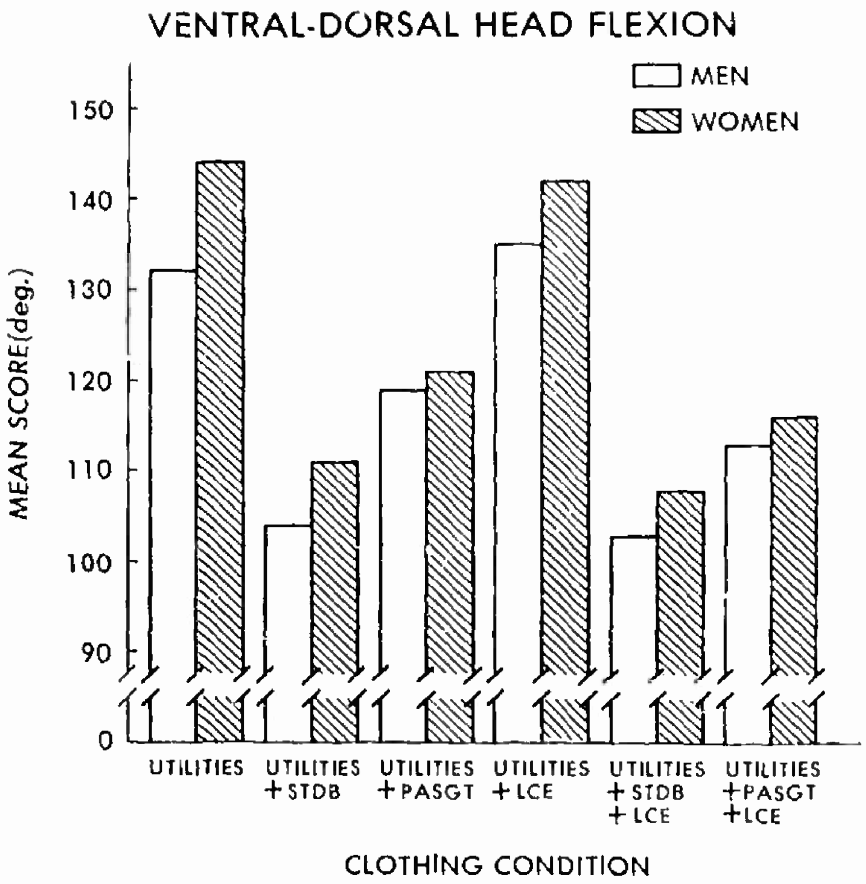
of the tasks (Table 7) that the score achieved with the utilities was slightly, but not significantly, lower than the best score on each task. Sex had a significant main effect on Upper Arm Abduction and Forward Extension (Tasks 5 and 6). There was also a significant interaction between sex and clothing condition on the latter task (Table B). The mean percentage scores on each task as a function of clothing condition and sex are presented in Figures 1b through 16b.

The first two tasks in the battery involved head movements. For the flexibility task requiring Ventral-Dorsal Head Flexion (Task/Figure 1), the mean raw score when the LCE was worn with the utilities did not differ from that for the utilities alone, and both these conditions yielded scores which were significantly higher than those achieved when armor vests were used. Mean raw scores for the two PASGT vest conditions were somewhat higher than those for the STD B vest conditions. However, only the score when the PASGT vest was worn without the LCE was significantly higher than that for either STD B vest condition (Table 7). In the analysis of the percentage scores for Ventral-Dorsal Head Flexion, use of the LCE without armor resulted in a score significantly higher than those achieved when armor was worn. As was found in the raw score analysis, the lowest scores were obtained when the STD B vest was worn and performance in the PASGT vest without the LCE was significantly superior to that for the two STD B conditions (Table 9).

The findings for Head Rotation (Task/Figure 2) were similar with regard to the ordering of the scores among the LCE and the armor conditions. Analysis of the raw scores indicated that the use of the LCE did not significantly affect performance levels relative to those achieved with utilities alone. The mean raw score for the PASGT vest was slightly, but not significantly, lower than that for the LCE. The use of the LCE with the PASGT vest resulted in scores that were significantly poorer than those obtained with the LCE alone, but they did not differ significantly from those achieved with the PASGT or the STD B vest alone. The lowest performance levels occurred when the STD B vest was used. The addition of the LCE to the STD B vest decreased scores relative to those achieved with the vest alone, but there was no significant difference between these two conditions (Table 7). In the analysis of the percentage scores for Head Rotation, there was no significant difference in the mean percentage scores for the two vests when they were worn without the LCE, nor did the scores achieved when the LCE was worn in combination with the vests differ significantly from each other (Table 9).

Two flexibility tasks involved bending at the waist. These were Standing and Sitting Trunk Flexion (Tasks/Figures 3 and 4). On both these tasks, the poorest performance occurred when the STD B vest was worn with the LCE. For Standing Flexion (Task/Figure 3), the mean raw score for utilities was highest and was significantly better than the mean score achieved when the LCE was worn with either armor vest, but the score for utilities did not differ from those for either vest alone or for the LCE alone. Also, there were no significant differences in the mean raw scores or the percentage scores for the LCE, the STD B vest, the PASGT vest, or the PASGT vest with the LCE conditions. However, when the LCE was used with the STD B vest, the mean raw score and the mean percentage score achieved were significantly worse than all others with the exception of the score for the PASGT vest and the LCE combination (Tables 7 and 9).

a



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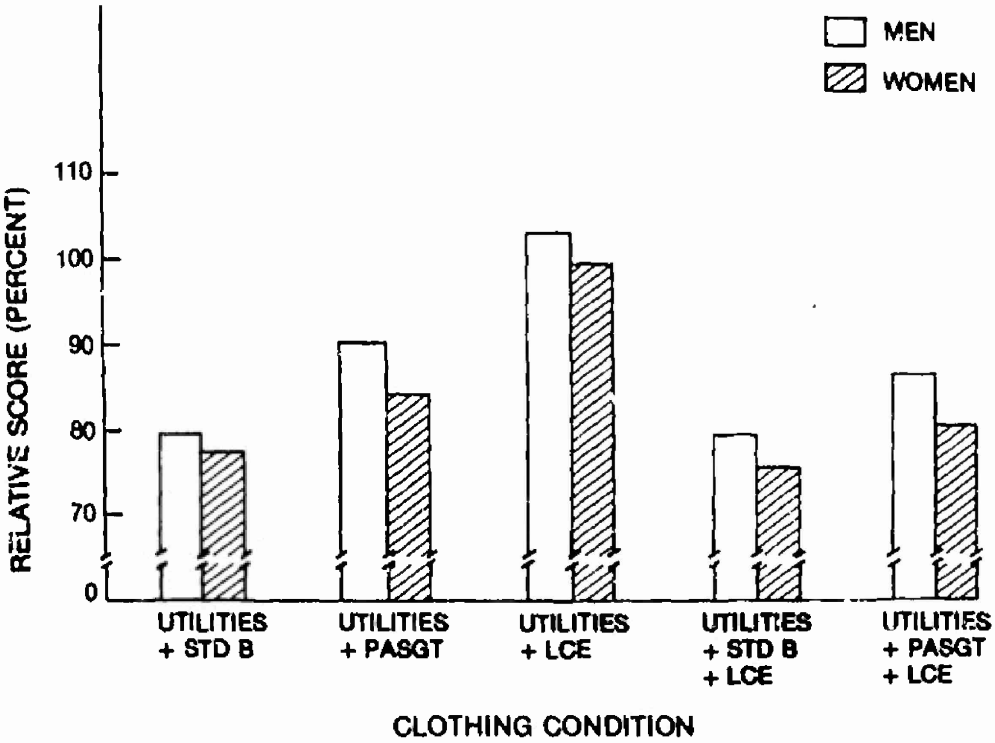


Figure 1. Mean raw score (a) and mean percentage score (b) on Ventral-Dorsal Head Flexion (Task 1) as a function of clothing condition.

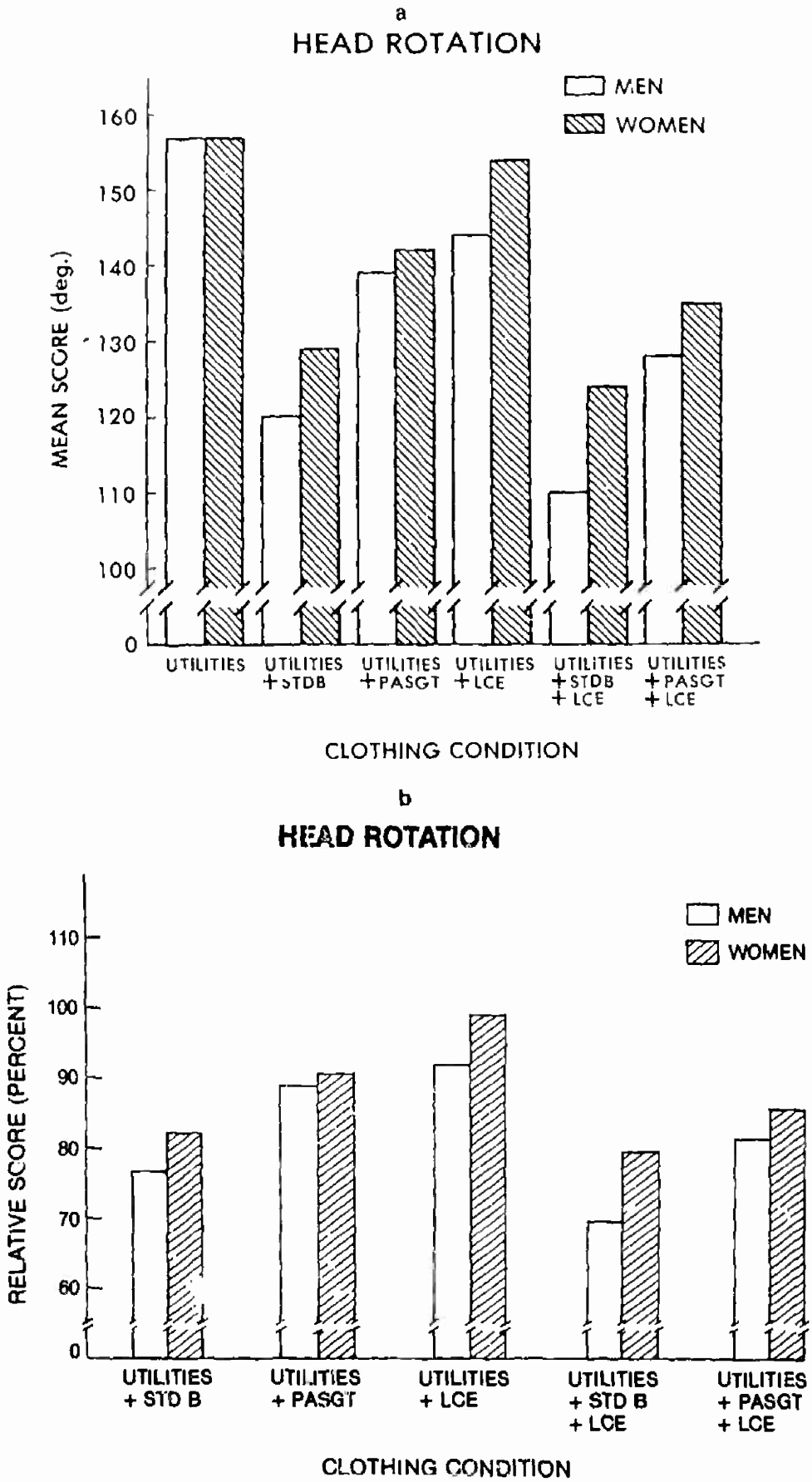
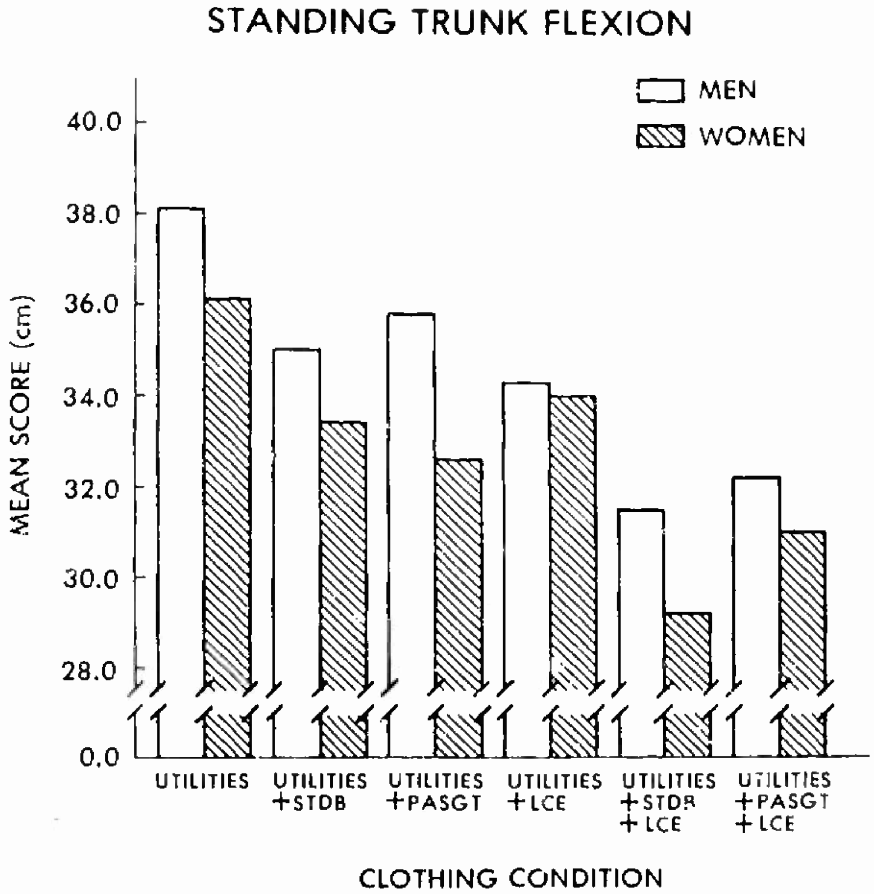


Figure 2. Mean raw score (a) and mean percentage score (b) on Head Rotation (Task 2) as a function of clothing condition.



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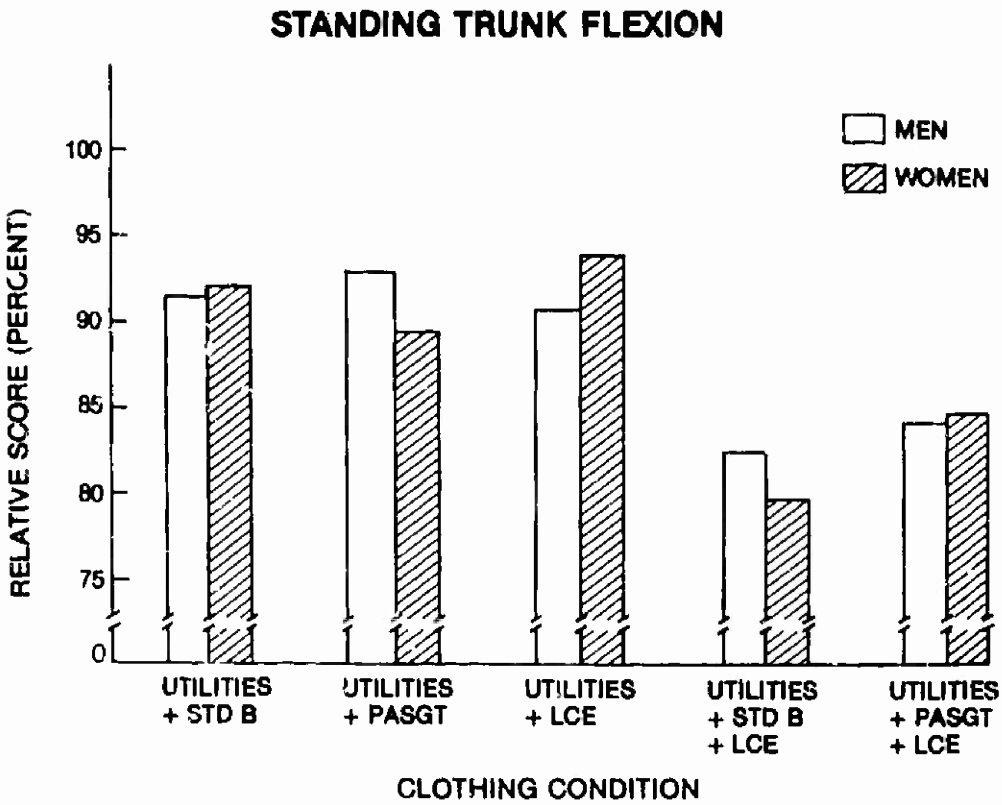


Figure 3. **Mean raw score (a) and mean percentage score (b) on Standing Trunk Flexion (Task 3) as a function of clothing condition.**

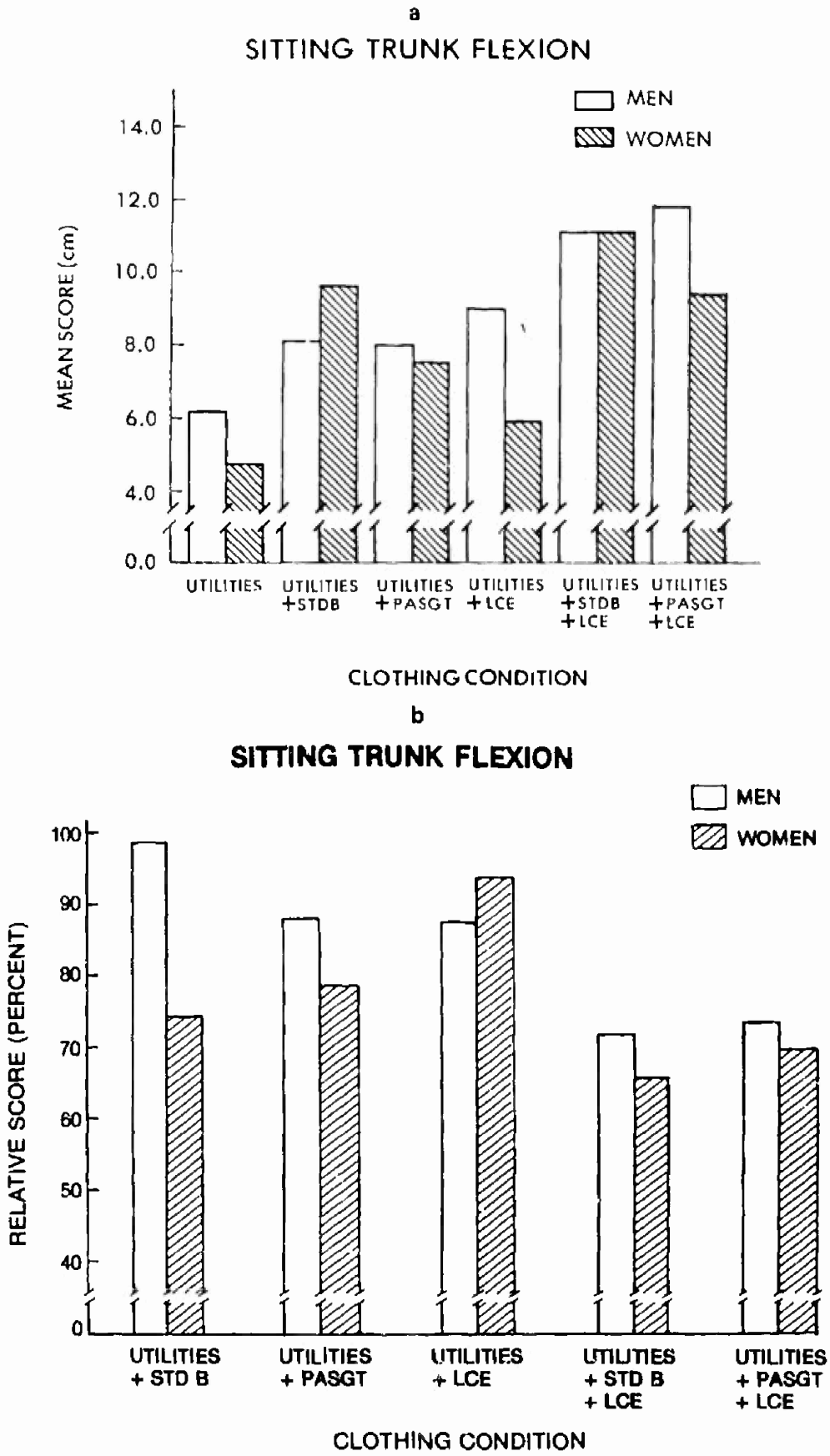


Figure 4. Mean raw score (a) and mean percentage score (b) on Sitting Trunk Flexion (Task 4) as a function of clothing condition.

On the Sitting Trunk Flexion task (Task/Figure 4), the relationship of the mean raw score when utilities were worn alone to those for the other conditions was the same as that obtained on the Standing Trunk Flexion task; when utilities were used, the performance level was highest and was significantly better than that achieved when either armor vest was used in combination with the LCE. The Newman-Keuls multiple comparison test performed on the mean percentage scores for Sitting Trunk Flexion did not result in significant differences between clothing conditions. Therefore, it may be assumed that the main effect of clothing was attributable to a significant difference between the highest mean percentage score, which was obtained when the LCE was used, and the lowest score, which occurred when the LCE was worn with the STD B vest. Neither the raw score nor the percentage score analyses yielded any other significant differences among clothing conditions on the Sitting Trunk Flexion task (Tables 7 and 9).

The next three flexibility tasks included in the performance battery involved movement of the upper arm and the effects of sex and clothing conditions varied among these movements. Upper Arm Abduction and Forward Extension (Tasks/Figures 5 and 6) were both significantly affected by the sex, as well as by the clothing, variables (Tables 6 and B). On upper Arm Abduction, the mean raw score for the men (129.44°) was higher than that for the women (110.80°). Calculation of the percentage scores for Upper Arm Abduction indicated that the performance level of the men for all clothing conditions, excluding the utilities alone, was B5.52% of the utilities' score, while that of the women was 77.02% of the utilities' score. With regard to the clothing effects as reflected in both the raw and the percentage scores, the extent of arm abduction when the LCE was worn with the STD B vest was significantly lower than abduction with any of the other clothing conditions. The mean raw score when utilities were used alone was significantly higher than all other scores. There were no significant differences among the mean raw scores for the LCE and the two conditions in which armor vests were worn without the LCE. However, the scores when either the LCE or the PASGT vest were worn alone were significantly higher than those achieved when the PASGT vest was worn with the LCE, while the mean raw score for the STD B vest was not (Table 7). The mean percentage scores for the PASGT vest alone and the LCE alone were equal and were significantly higher than all others. Percentage scores for the STD B armor and for the PASGT vest with the LCE did not differ from each other, but both were significantly better than that for the STD B vest with the LCE (Table 9).

For Upper Arm Forward Extension (Task/Figure 6), the men's raw scores and percentage scores (143.35° and 90.75% respectively) were again significantly higher than those for the women (129.62° and B4.42%, respectively). The mean raw score for utilities was significantly higher than all others except the score achieved when the LCE was used without armor. The mean raw score for the LCE condition did not differ significantly from the scores for either of the PASGT vest conditions, but it was significantly better than the raw scores obtained when the STD B vest was worn with or without the LCE. When the PASGT vest was used with or without the LCE, the mean raw scores were significantly higher than those for the STD B worn in combination with the LCE, but they were not higher than those achieved with the STD B vest alone (Table 7). The relationship among the mean percentage scores were similar to those for the raw scores with one exception; use of the LCE did not result in a performance level that was significantly higher than the level achieved with the STD B vest (Table 9).

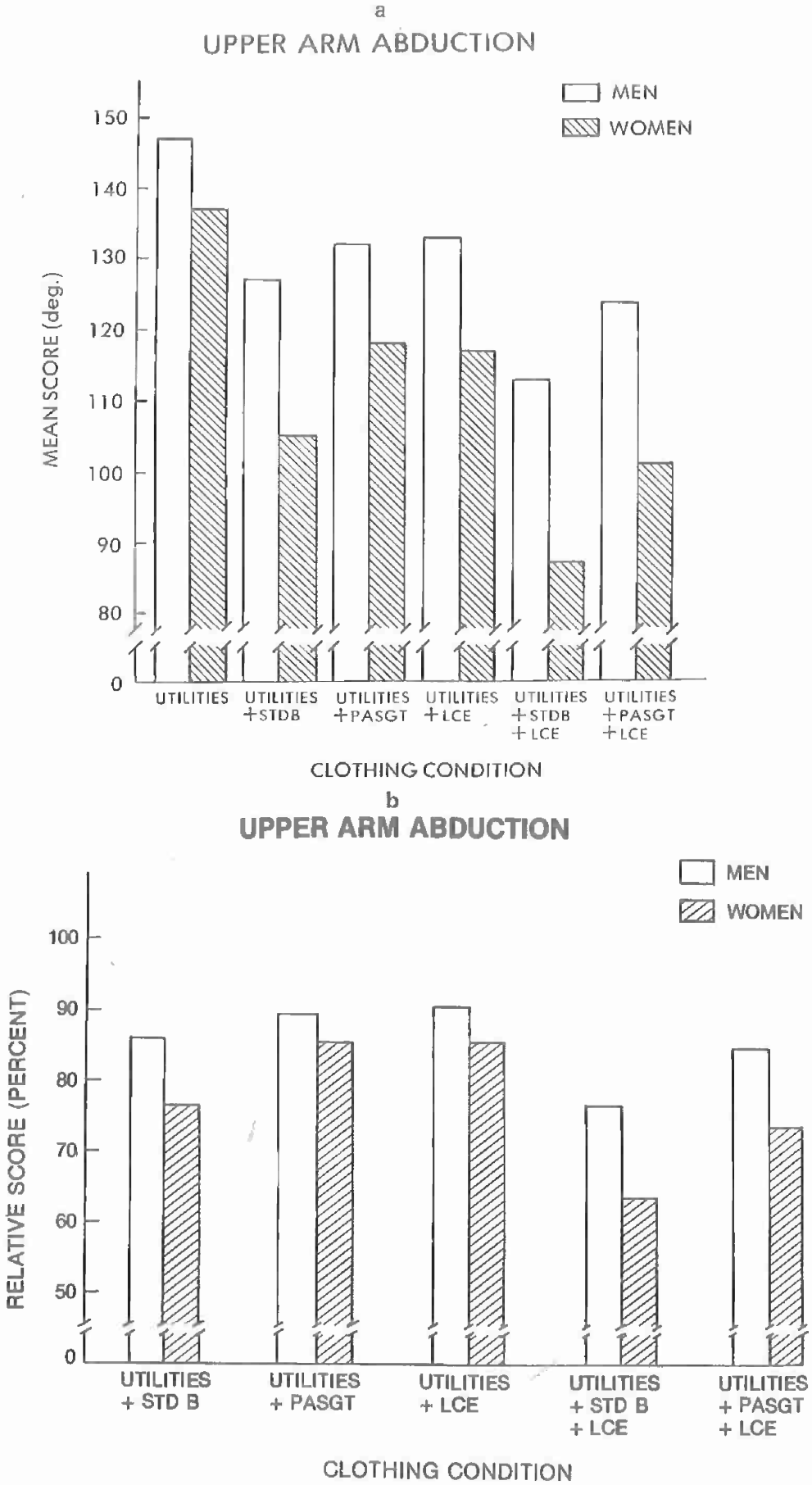


Figure 5. Mean raw score (a) and mean percentage score (b) on Upper Arm Abduction (Task 5) as a function of clothing condition.

Figure 6. Mean raw score (a) and mean percentage score (b) on Upper Arm Forward Extension (Task 6) as a function of clothing condition.

Both the raw score and the percentage score analyses of Upper Arm Forward Extension yielded a significant interaction between clothing conditions and sex (Tables 6 and 8). This finding is attributable to the fact that the performance level of the men was higher when they wore the PASGT vest than when they wore the LCE and the opposite was true for the women.

Analysis of the raw scores for the third arm flexibility task, Upper Arm Backward Extension (Task/Figure 7), yielded a significant main effect attributable to clothing condition (Table 6). This finding indicated that there was a significant difference between the two extreme mean scores, those for the utilities only and the STD B vest conditions, although the Newman-Keuls test applied to these data did not yield any significant differences among conditions (Table 7). No significant effects were obtained in the percentage score analysis (Table 8).

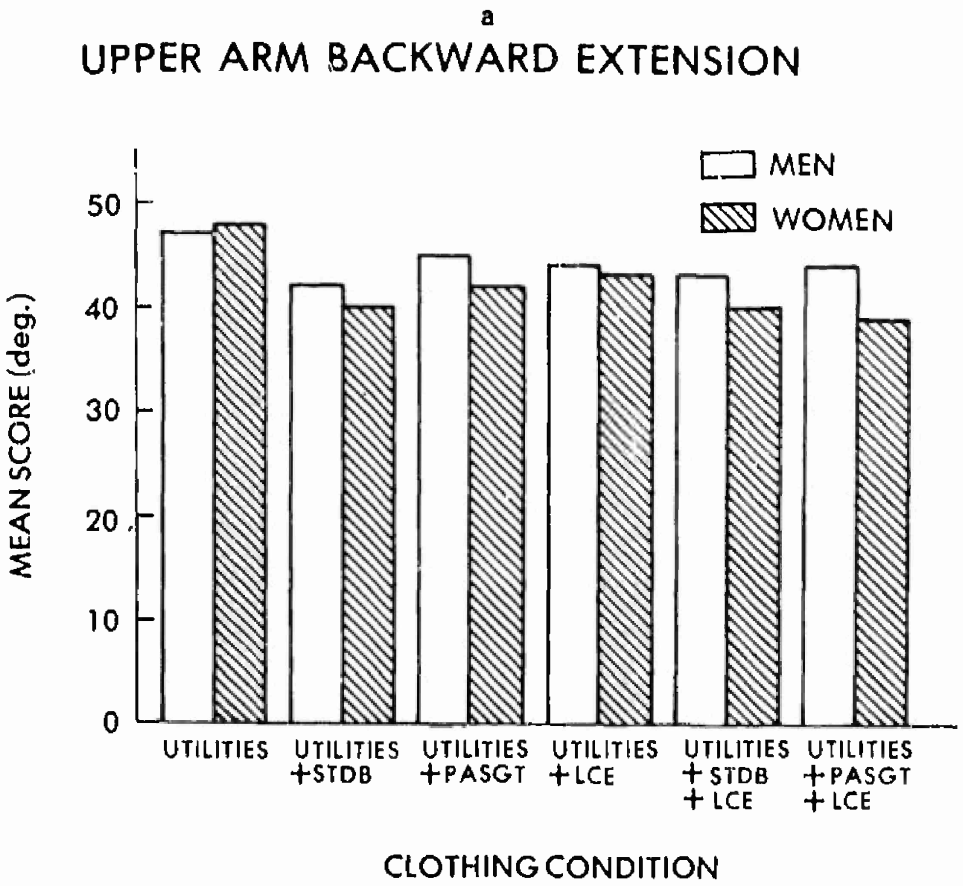
The three remaining flexibility tasks in the battery involved leg movements. None of these tasks were affected by the sex variable (Tables 6 and 8) and, again, the effects of the clothing conditions varied with the movement required. The highest mean raw score for Upper Leg Abduction (Task/Figure 8) was obtained with the utilities. This score was significantly better than the two lowest scores which were obtained when either vest was worn with the LCE. The use of the LCE alone resulted in a performance level which was significantly higher than that which occurred when the LCE and the STD B vest were worn in combination. There were no other significant differences among the mean raw scores on this task (Table 7). A significant clothing effect on leg abduction capabilities was also obtained when the percentage scores were analyzed (Table 8), although the Newman-Keuls multiple comparison test performed on these data did not yield any significant differences among scores. Therefore, only the clothing conditions associated with the two extreme mean percentage scores can be said to have differed significantly from each other. The highest percentage score was obtained when the PASGT vest was worn and the lowest when the LCE was used in combination with the STD B vest (Table 9).

With regard to the two remaining leg flexibility movements, Upper Leg Forward Extension (Task/Figure 9) and Upper Leg Flexion (Task/Figure 10), the raw score analysis performed on the latter was the only one for which significant effects were obtained. The amount of leg flexion achieved when the utilities were worn alone was significantly greater than that achieved when the PASGT vest and the LCE were worn in combination (Table 7).

Raw and percentage scores on the Pursuit Rotor (Task/Figure 11), one of the two psychomotor tests included in the battery, were significantly affected by the clothing variable. The highest mean times-on-target were obtained when the PASGT vest was worn without the LCE. The mean raw score for this condition was significantly better than the lowest score, which occurred when the STD B vest was worn with the LCE (Table 7). The mean percentage score for the PASGT vest was significantly higher than the two lowest scores which were associated with the two vest plus LCE combinations (Table 9). There were no other differences among the clothing conditions on the Pursuit Rotor.

The raw scores of one of the rate of movement tests investigated in this study, the Figure-8 Run and Duck (Task/Figure 12), yielded a significant sex effect (Table 6). When mean raw scores were computed by summing over all clothing conditions, it was found that the men

a



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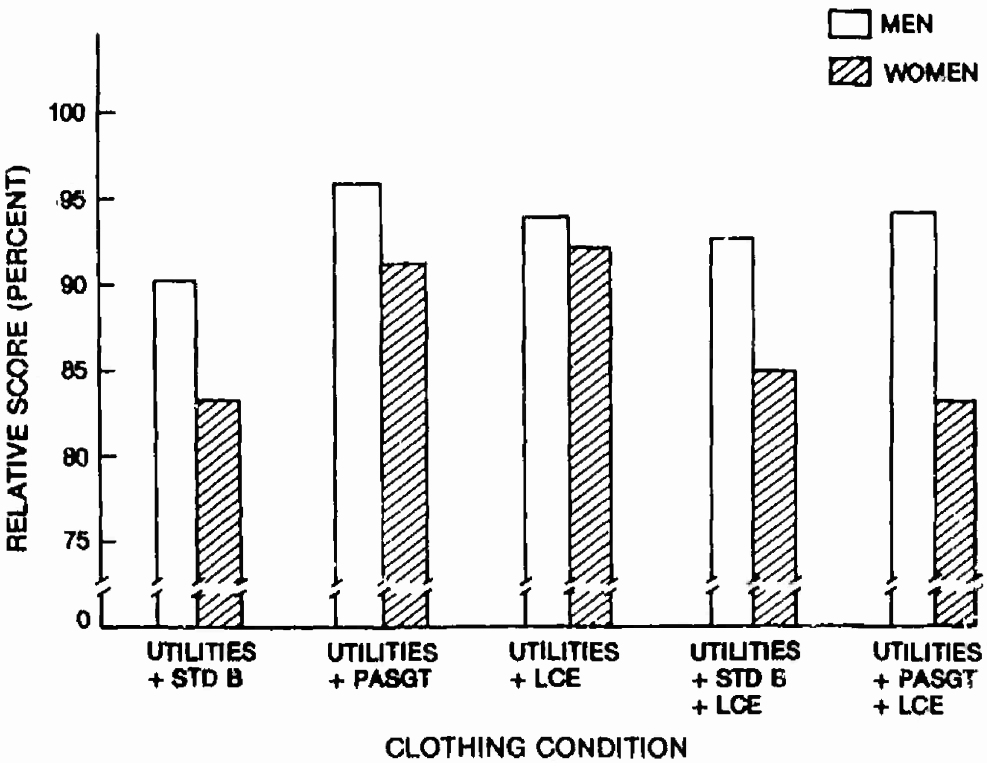


Figure 7. Mean raw score (a) and mean percentage score (b) on Upper Arm Backward Extension (Task 7) as a function of clothing condition.

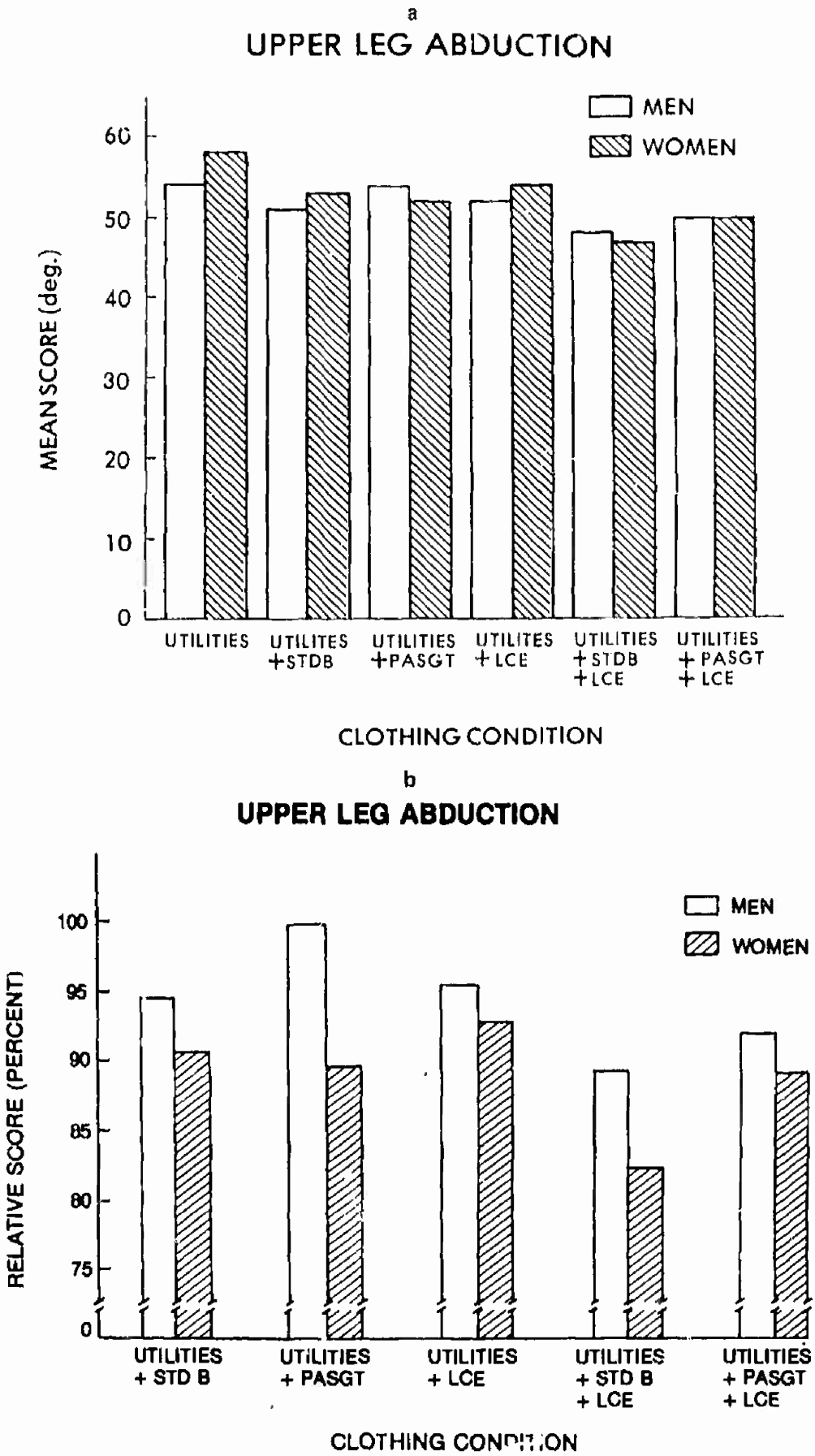
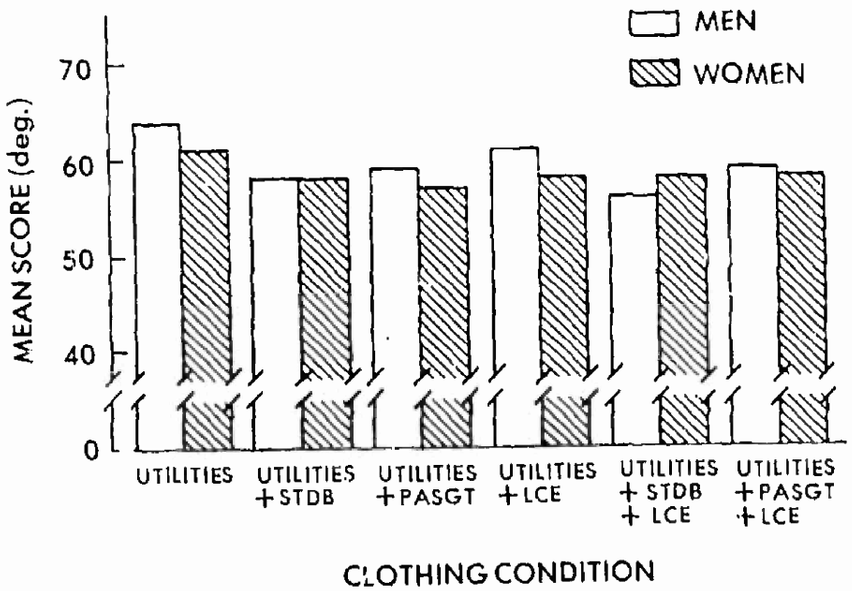


Figure 8. Mean raw score (a) and mean percentage score (b) on Upper Leg Abduction (Task 8) as a function of clothing condition.

a

UPPER LEG FORWARD EXTENSION



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UPPER LEG FORWARD EXTENSION

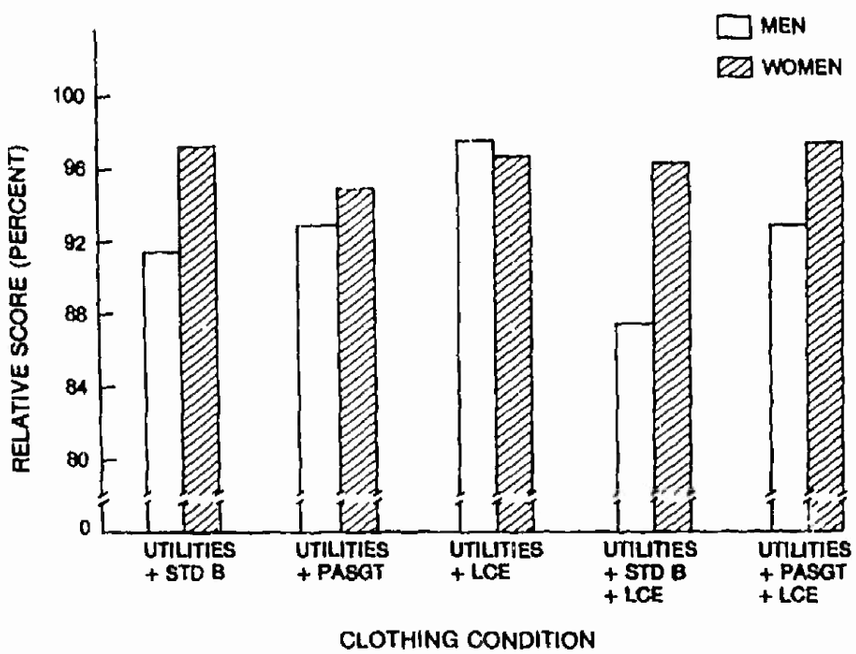
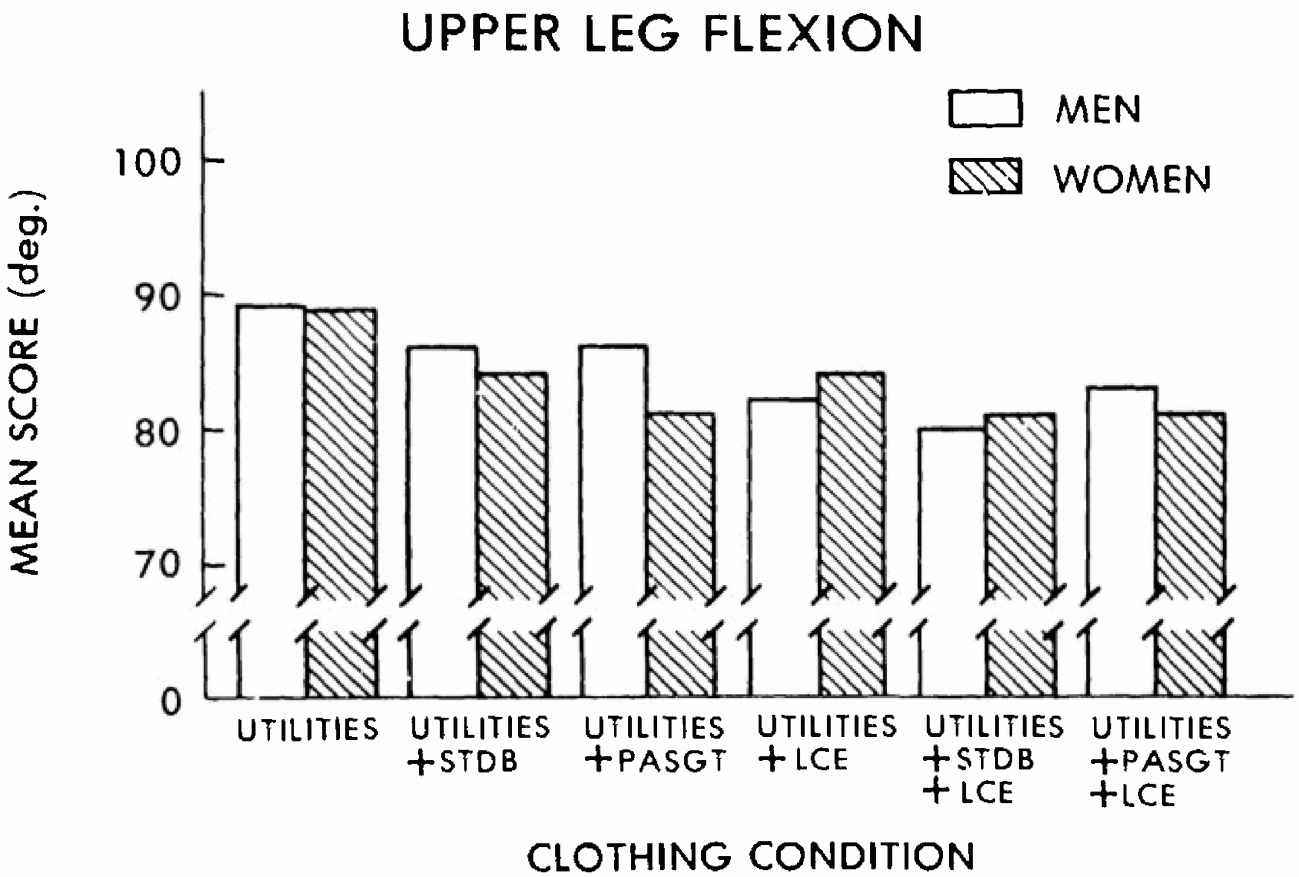


Figure 9. Mean raw score (a) and mean percentage score (b) on Upper Leg Forward Extension (Task 9) as a function of clothing condition.

a



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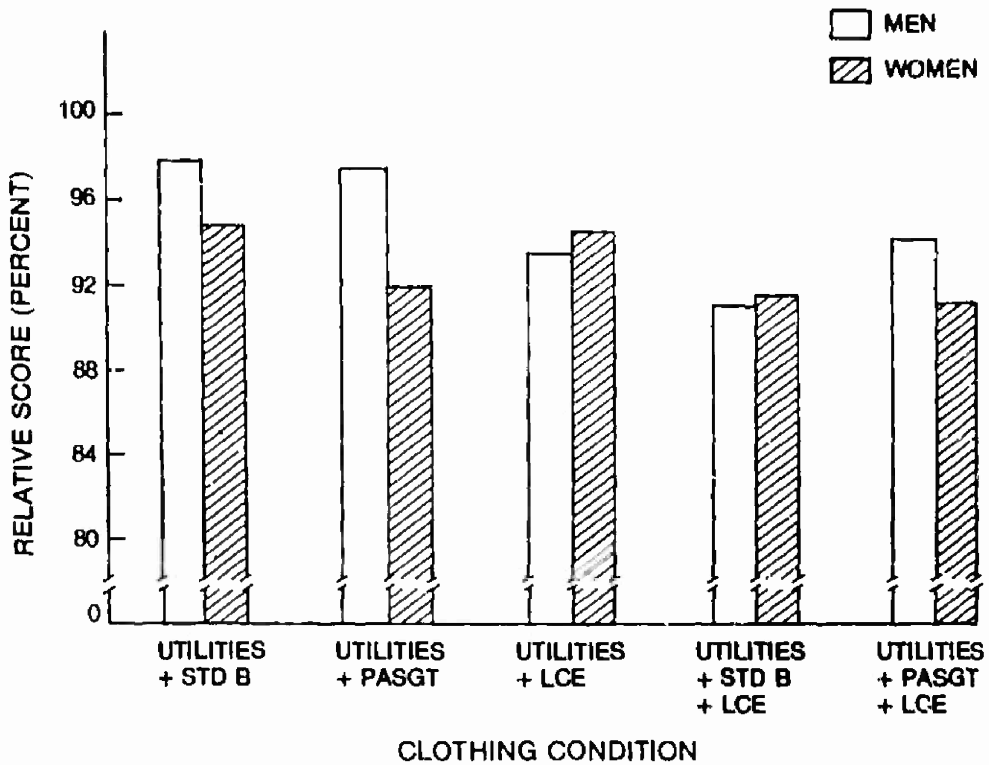


Figure 10. Mean raw score (a) and mean percentage score (b) on Upper Leg Flexion (Task 10) as a function of clothing condition.

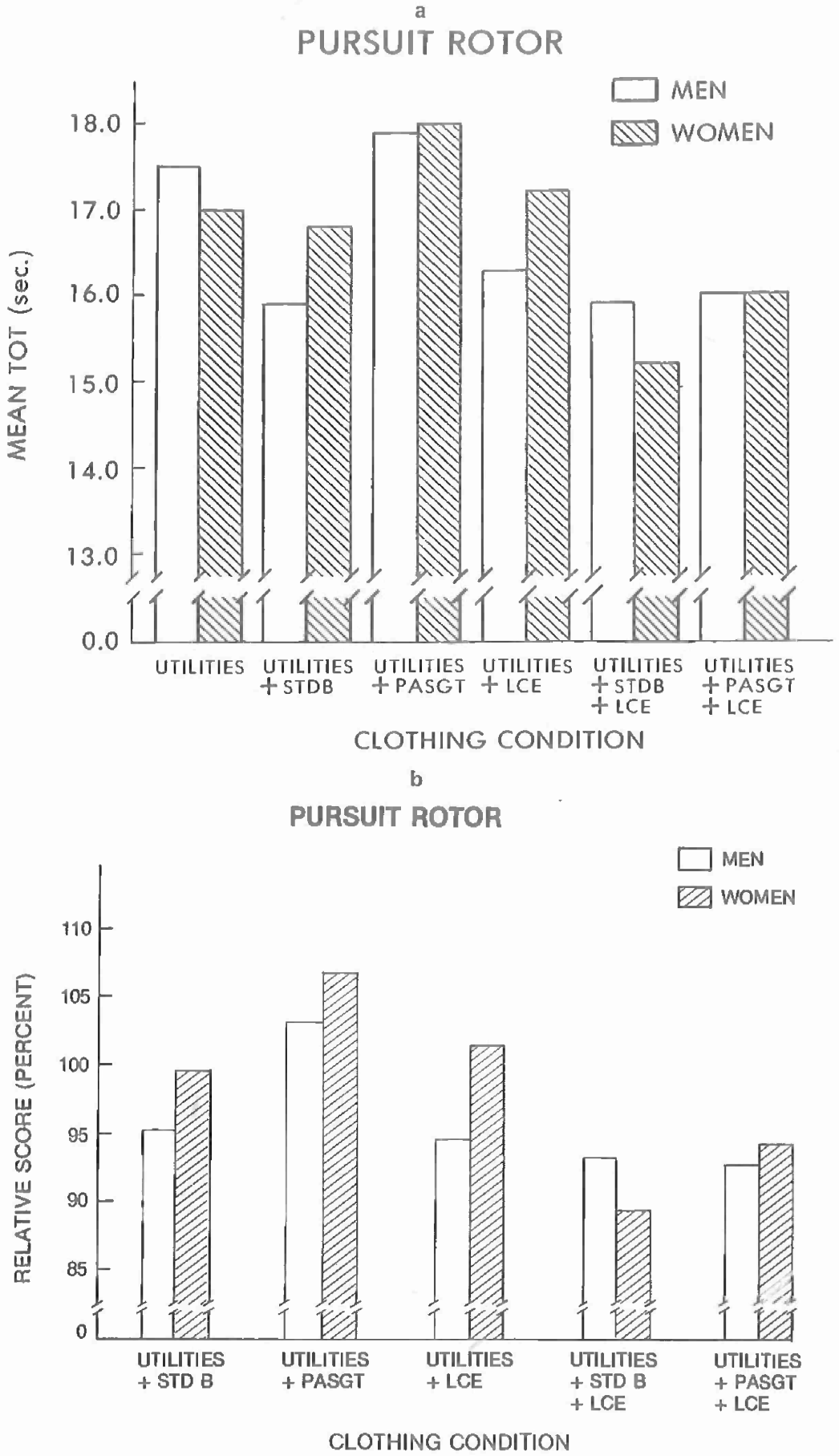
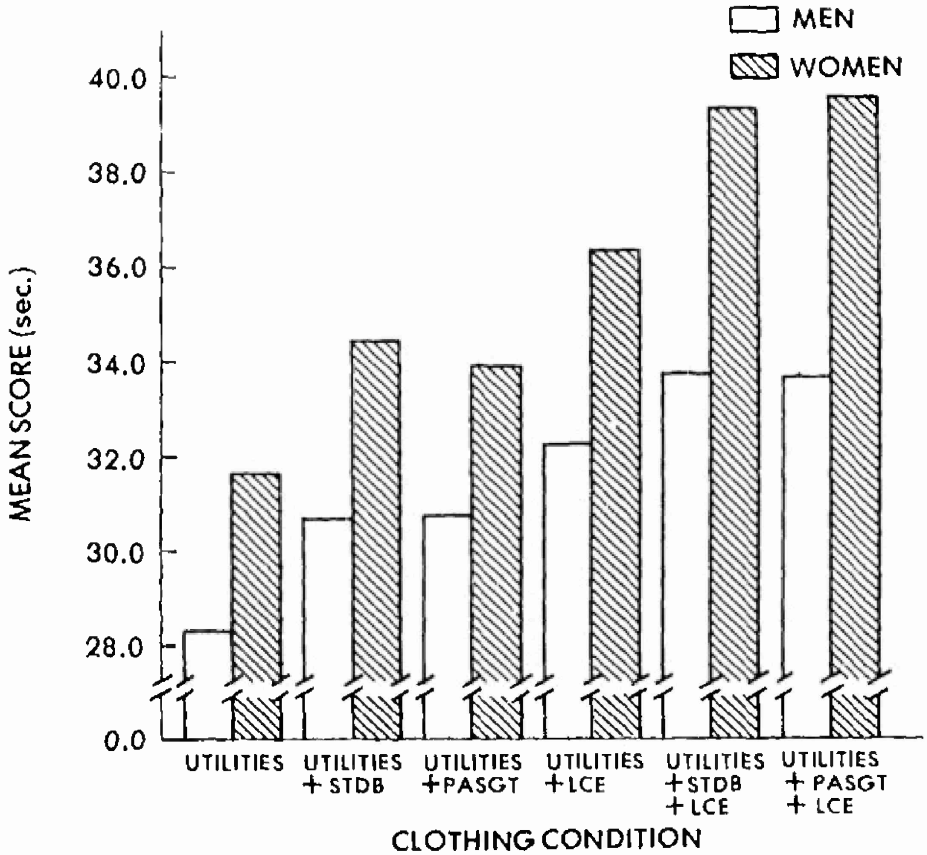


Figure 11. Mean raw score (a) and mean percentage score (b) on the Pursuit Rotor Test (Task 11) as a function of clothing condition.

a

FIGURE-8 RUN AND DUCK



b

FIGURE-8 RUN AND DUCK

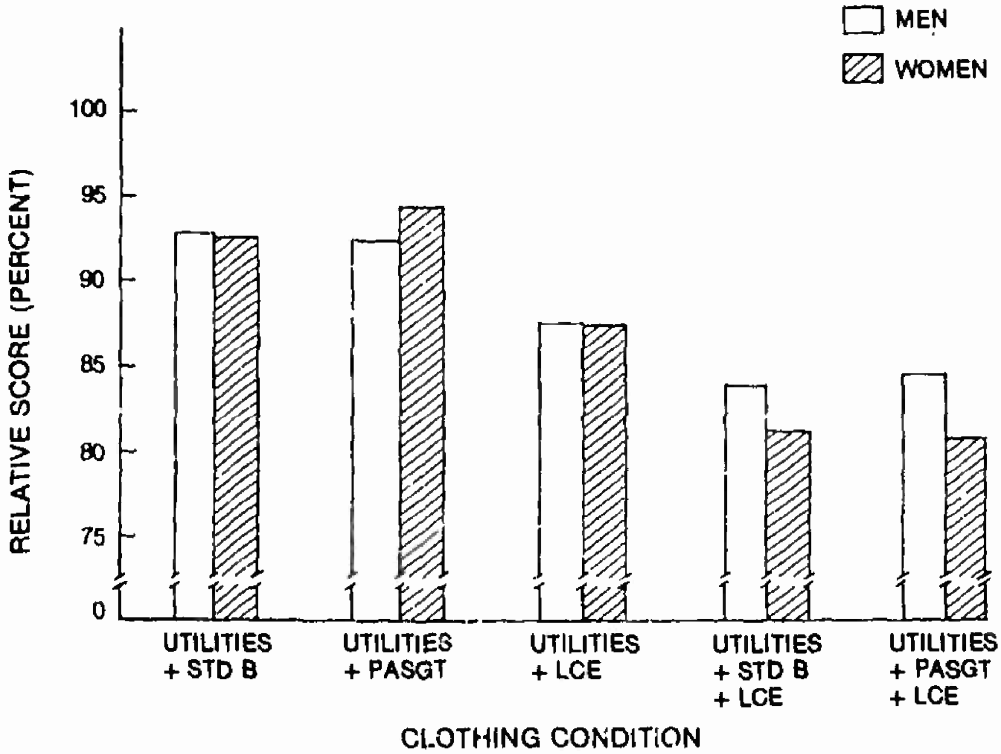


Figure 12. Mean raw score (a) and mean percentage score (b) on the Figure-8 Run and Duck (Task 12) as a function of clothing condition.

completed the task in 31.6 sec while the women required 35.9 sec. There was no difference between the sexes in the percentage score analysis (Table 8). With regard to the effects of the clothing variable on the time to completion of this task, the mean raw score when the utilities alone were worn was significantly better than all others and the scores for the two conditions in which the LCE was worn with the vests were significantly worse than all others. There were no differences among the mean raw scores when either of the vests or the LCE were worn alone (Table 7). The mean percentage scores obtained when the LCE was used with either the PASGT or the STD B vest were also significantly worse than all others and these two conditions did not differ significantly from each other. When either vest was worn alone, the mean percentage scores were significantly better than all others (Table 9).

The raw scores on both of the manual dexterity tests included in the present battery were significantly affected by the sex of the participants (Table 6). The women completed the O'Connor Finger Dexterity Test (Task/Figure 13) in 68.78 sec, while the men required 83.81 sec. On the Bennett Hand Tool Dexterity Test (Task/Figure 14), the performance time for the men (139.49 sec) was significantly faster than that for the women (156.98 sec). On the O'Connor Test, there were no significant effects attributable to clothing. However, both the raw score and the percentage score analyses performed on the Bennett data yielded significant clothing effects (Table 6 and 8). The best mean raw score was achieved when the utilities were worn alone and the worst when the LCE was used in combination with the STD B vest (Table 7). Among the percentage scores, the highest performance level occurred when the PASGT vest was used, and the STD B vest with the LCE again resulted in the lowest performance level (Table 9).

On the Railwalk (Task/Figure 15), the second psychomotor coordination test in the battery, the best mean raw score was achieved when the utilities were worn alone and the lowest score, which differed significantly from the score for utilities, occurred when the LCE was worn with the PASGT vest. There were no other significant differences among the raw scores for the clothing conditions (Table 7). For the percentage scores, the highest mean was obtained when the PASGT vest was worn alone and the lowest when the LCE was worn over this vest (Table 9). Although no significant differences between men and women were obtained in the percentage score analysis, the raw score analysis indicated that the men walked significantly further on the rail (176.6 cm) than the women did (129.9 cm) (Table 6).

The raw scores on the other rate of movement test included in the performance battery, the Ball-Pipe Test (Task/Figure 16), were also significantly affected by the clothing variable (Table 6). The highest mean raw score was achieved when the utilities were worn alone. The scores decreased somewhat, but not significantly, when either the PASGT vest or the LCE was used. Performance levels with the STD B vest alone and with the PASGT vest worn with the LCE were significantly lower than performance with the utilities, but did not differ from either the PASGT vest alone or the LCE alone conditions. The lowest mean score occurred when the LCE was worn in combination with the STD B vest. This score was significantly lower than the scores for all conditions except the STD B vest and the PASGT vest with the LCE (Table 7). The percentage scores were also similarly affected by the clothing variable. The highest mean percentage scores were obtained when either the PASGT vest or the LCE was worn alone. These scores differed significantly from the lowest score which occurred when the STD B vest was worn in combination with the LCE. There were no other significant differences among the clothing conditions (Table 9).

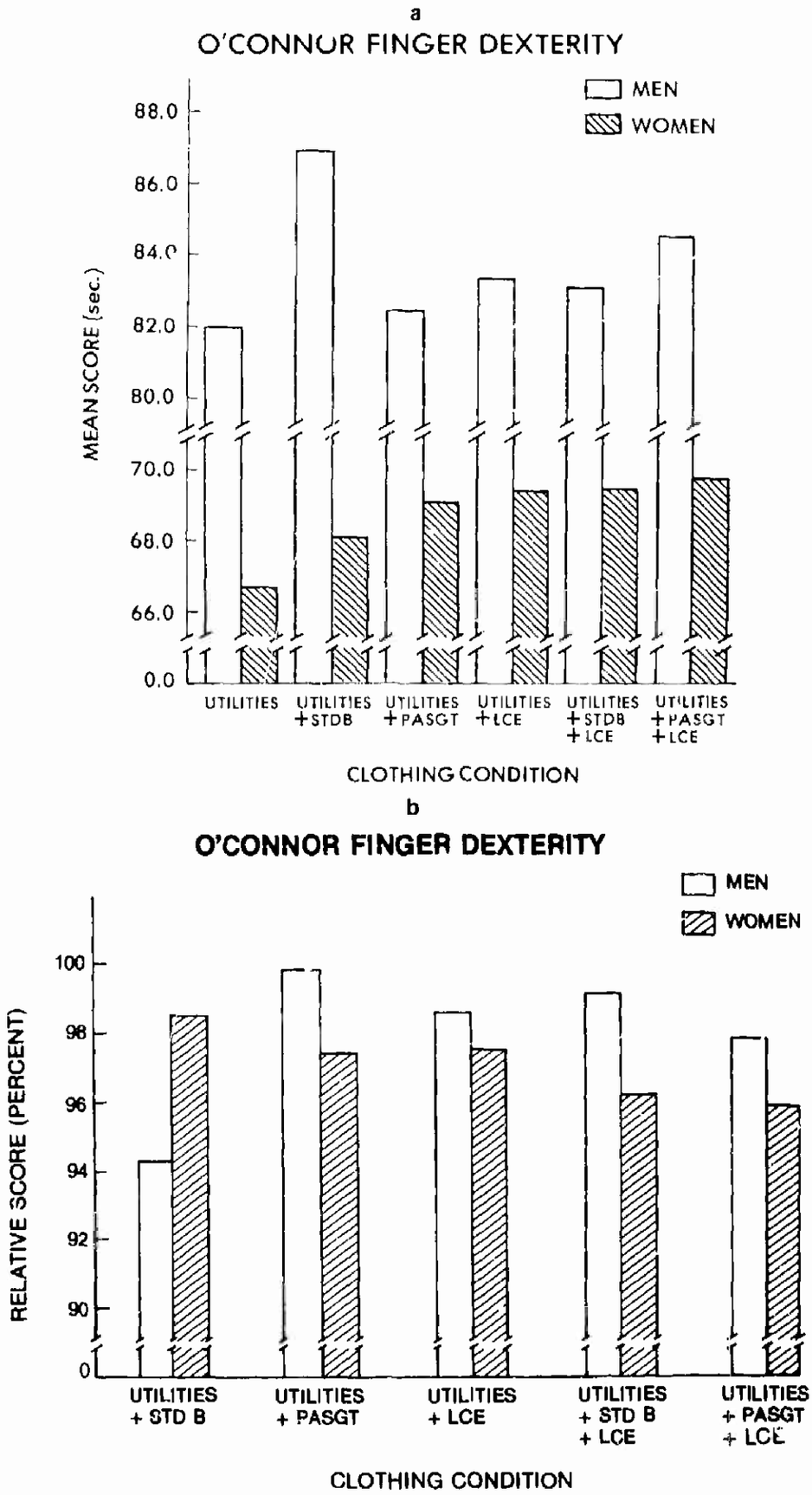


Figure 13. Mean raw score (a) and mean percentage score (b) on the O'Connor Finger Dexterity Test (Task 13) as a function of clothing condition.

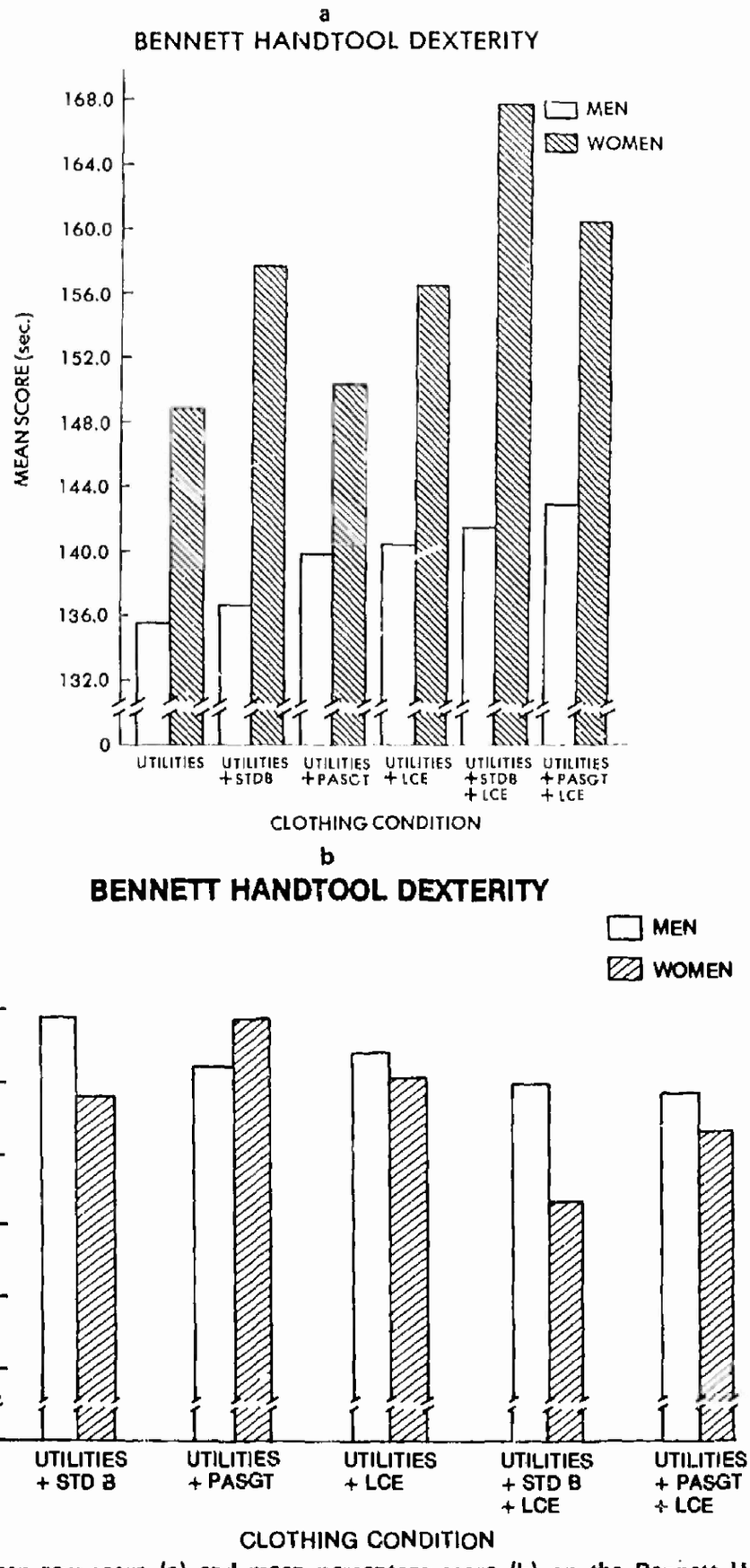


Figure 14. Maan raw score (a) and maan parcantage scora (b) on the Bennett Hand Tool Daxtarity Test (Task 14) as a function of clothing condition.

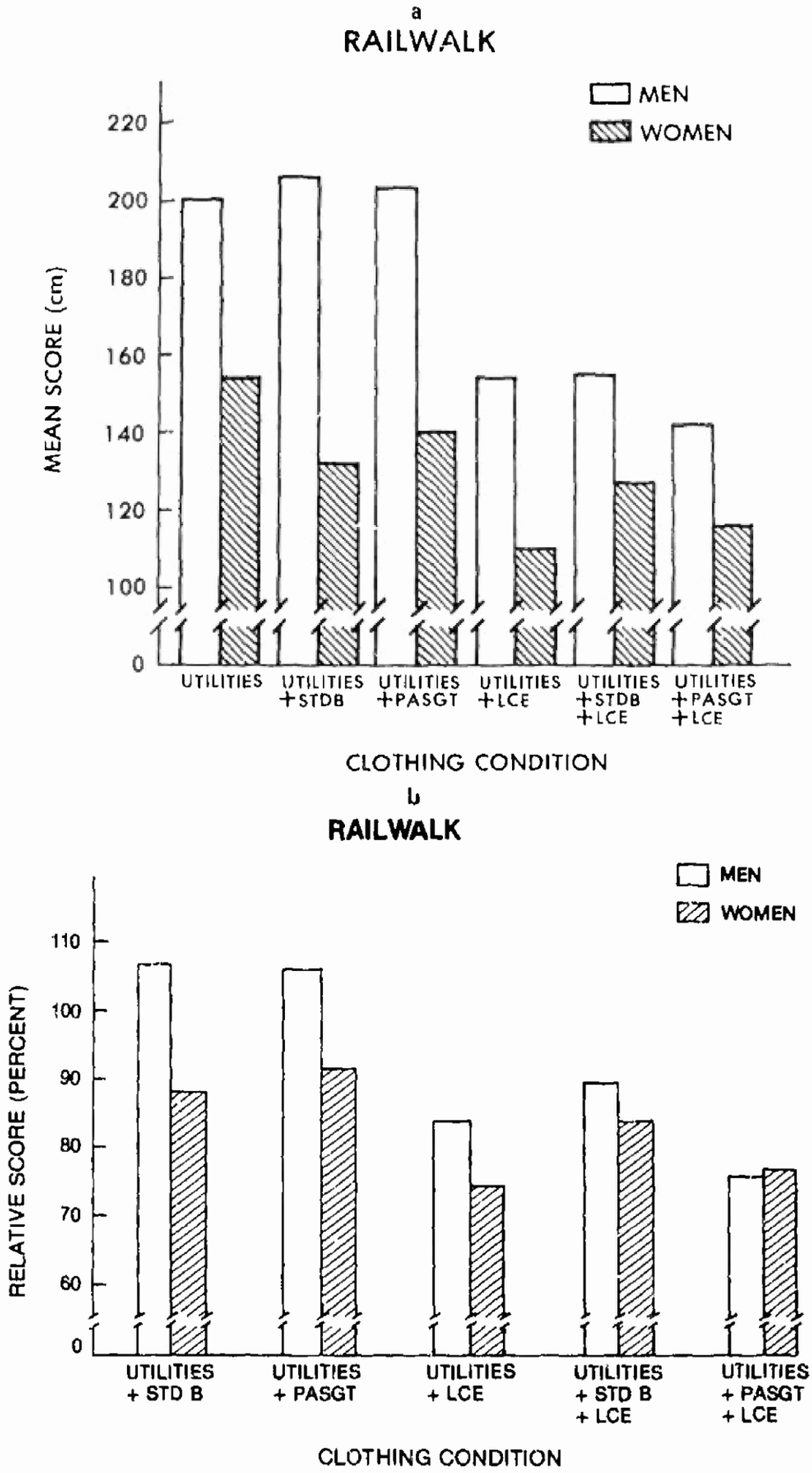


Figure 15. Mean raw score (a) and mean percentage score (b) on the Railwalk (Task 15) as a function of clothing condition.

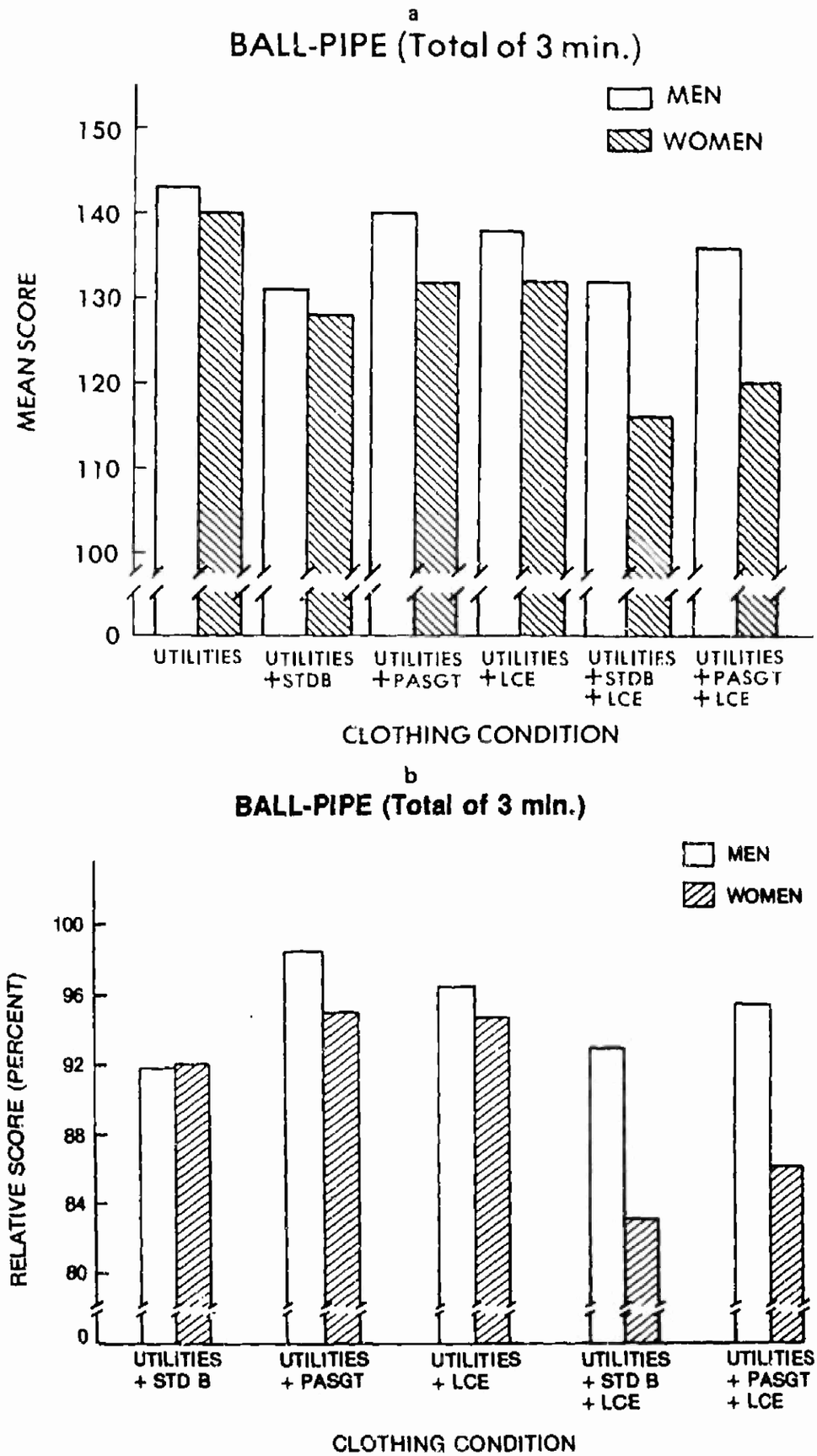


Figure 16. Mean raw score (a) and mean percentage score (b) on the Ball-Pipe Test (Task 16) as a function of clothing condition.

Analysis of the raw scores for the Ball-Pipe Test also yielded a significant interaction between clothing condition and sex (Table 6). Both the men and the women obtained their highest scores when the utilities were worn alone, followed by the PASGT vest, and then the LCE scores. The relationship among the scores achieved on the three remaining clothing conditions varied as a function of sex. The three lowest scores for the men, in descending order, were obtained for the PASGT vest and the LCE combination, the STD B vest and the LCE combination, and, finally, the STD B vest worn alone. For the women, the order of the three lowest scores was as follows: STD B vest, PASGT vest plus the LCE, and STD B vest plus the LCE (Figure 16).

Heart Rate Data

In the analysis of variance performed on readings 2 and 4 of the heart rate data, the reading variable had a significant effect with the fourth heart rate reading, taken after completion of the test battery, being lower (99.9 beats/min.) than heart rate at the completion of the Figure-B Run and Duck (107.1 beats/min.) (Figure 17). Analysis of the heart rate data did not yield any other significant sources of variance (Table 10).

Questionnaire Data

On the first question of Section I (Appendix D), the subjects were asked to rank from 1 to 3 the three flexibility movements and the three psychomotor tasks which were most impaired by each clothing condition. Scores of 3, 2, and 1 were assigned to ranks of 1, 2, and 3, respectively. Therefore, higher scores are associated with higher impairment ratings. The sums of these scores across subjects for each task, clothing condition, and sex are presented in Table 11. Among the flexibility tasks, the men gave higher impairment ratings to the two waist flexion tasks than the women did, while the women gave higher ratings to the three arm movements than the men did. The relationship among the impairment ratings given to the clothing conditions varied as a function of flexibility task. For example, on Ventral-Dorsal Head Flexion and Head Rotation, the lowest impairment ratings, with the exception of those given to the utilities, were assigned to the condition in which the LCE was worn alone. On Standing Trunk Flexion and Upper Leg Flexion, the LCE, when used alone, was judged to have impaired performance more than any other clothing condition. There were no distinct or systematic differences on the flexibility tasks between the impairment ratings given to the two types of armor vest or to either vest as a function of the presence or absence of the LCE.

Among the psychomotor coordination tasks, the Figure-B Run and Duck and the Ball-Pipe Tests were judged by both men and women to have been more impaired by the LCE and the armor tested than any of the remaining tasks, relative to the condition in which utilities were worn alone. The men and women gave the highest impairment ratings on the Figure-B Run and Duck Test to the condition in which the LCE was worn with the PASGT vest. On the Ball-Pipe Test, the men gave their highest impairment rating to the STD B vest and the women gave their highest rating to the STD B vest plus LCE combination.

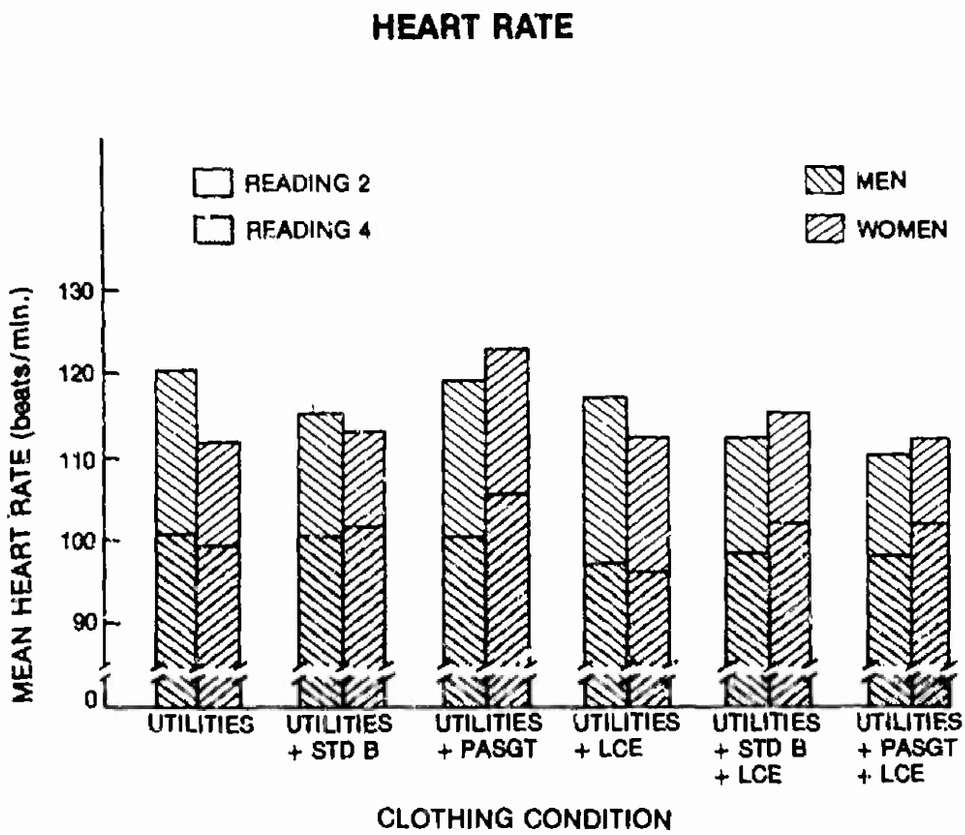


Figure 17. Mean Heart Rate as a function of clothing condition and reading.

Table 10

Analysis of Variance of Heart Rate Data

Source of Variance	df	MS	F	p
Sex (A)	1	29.39	<1.00	
Ss/A	22	2860.99		
Clothing (C)	5	245.52	1.85	
A x C	5	153.29	1.16	
Ss x C/A	110	132.43		
Reading (R)	1	16140.06	73.31	.001
A x R	1	186.89	<1.00	
C x R	5	98.22	2.28	
A x C x R	5	22.19	<1.00	
Ss x C x R/A	110	43.08		

Table 11

Subjects' Summarl Ratings of the Impairment of Each Task by Each Clothing Condition

Battery	Clothing Condition: Utilities Men	Utilities Women	STD B Men	STD B Women	PASGT Men	PASGT Women	LCE Men	LCE Women	STD B +LCE Men	STD B +LCE Women	PASGT +LCE Men	PASGT +LCE Women
Movements												
Head Flexion	0	0	10	18	12	10	3	0	15	13	5	10
Head Rotation	0	0	13	8	8	2	3	0	8	1	4	5
Standing Flexion	3	0	9	5	9	4	21	11	8	3	9	5
Sitting Flexion	5	0	7	3	12	7	15	6	11	12	17	9
Arm Abduction	5	0	18	18	12	18	9	14	18	20	14	17
Arm Forward	1	0	2	5	4	5	1	9	4	9	3	10
Arm Backward	8	0	10	16	7	17	8	4	0	7	4	11
Leg Abduction	3	3	1	1	8	4	0	1	3	0	6	0
Leg Forward	4	0	2	0	3	2	5	6	8	2	6	1
Leg Flexion	1	0	0	0	0	5	8	12	1	5	4	4
Tasks												
Pursuit Rotor	0	5	6	4	6	2	1	3	4	7	7	1
Figure-8	7	2	20	20	23	21	20	22	25	20	32	28
O'Connor	7	2	0	4	4	3	5	5	4	1	2	0
Bennett	8	3	11	11	8	13	8	10	5	8	7	11
Railwalk	8	0	6	1	6	8	17	15	11	5	5	5
Ball-Pipe	10	8	26	28	23	24	21	13	23	31	19	25

For Question 2 of Section I the subjects ranked from 1 to 5 those clothing design characteristics which most impaired their performance on the flexibility and the psychomotor tasks (Appendix D). Scores of 5 through 1 were assigned to ranks of 1 through 5, respectively, and the sums of these scores across subjects for each design characteristic, clothing condition, and sex are presented in Table 12. For the flexibility tasks, the design characteristics of bulk and weight received the highest overall ratings. The weight and the bulk of the PASGT vest worn with the LCE were rated by both the men and the women as having impaired performance more than that of any of the other clothing conditions. Collar flexibility, protruding parts, and shoulder width and flexibility also received high ratings relative to the other design characteristics. Collar flexiblity was given a higher impairment rating when the STD B armor was worn than when the PASGT vest was used and the highest impairment ratings for protruding parts were associated with the LCE condition. With regard to the impact of shoulder width on performance of the flexibility tasks, the women gave higher impairment ratings to all the armor and the LCE conditions than the men did. Also, the men indicated that the shoulder width of the STD B vest, worn with or without the LCE, resulted in greater performance impairment than that of the PASGT vest, whereas the women assigned slightly higher ratings to the PASGT vest than they did to the STD B vest. In terms of flexibility, the women gave higher impairment ratings to the STD B vest than to the PASGT, regardless of the presence or absence of the LCE, while the men rated the STD B higher than the PASGT vest only for those conditions in which the LCE was not used with the vests.

With regard to the design characteristics that interfered with performance of the psychomotor coordination tasks, bulk, weight, and shoulder flexibility were again given high ratings. The bulk of the PASGT vest plus the LCE combination was rated slightly higher than the remaining clothing conditions by both the men and the women. With regard to the impact of shoulder flexibility, the women gave the highest impairment ratings to the PASGT vest when it was worn alone and the men gave the highest ratings to the STD B vest.

Questions 1 and 2, Section II, of the questionnaire (Appendix D) were restatements of the previous question. However, the subjects were to rate each design characteristic on a five-point scale from "no importance" to "extreme importance" in impairing or aiding performance. Median ratings were obtained for each design characteristic by assigning a numerical value to each point on the scale, from "1" for "no importance" to "5" for "extreme importance." Therefore, the higher the median rating, the greater the importance of the design characteristic. The median impairment ratings for each design characteristic are presented in Table 13 and the ratings given for aiding performance are presented in Table 14.

In general, the impairment ratings given by both the men and the women to the two STD B vest conditions were slightly higher than those given to the respective PASGT vest conditions. Also, bulk, weight, and shoulder flexibility were again among those design characteristics which received relatively high ratings for impairing performance. Bulk and weight were rated as being at least moderately important in impairing performance under all clothing conditions except the condition in which utilities were worn alone. The women's highest median impairment ratings for bulk and weight were assigned to the two conditions in which the LCE was worn with the armor vests. Here, they judged both design characteristics to be of considerable to extreme importance in impairing performance. The men assigned their highest median ratings for bulk to the STD B vest alone and to the PASGT vest worn with the LCE,

Table 12

Subjects' Summed Ratings of the Importance of Each Design Characteristic in Impairing Performance for Each Clothing Condition

Design Characteristics	Clothing Conditions: Utilities		STD B		PASGT		LCE		STD B +LCE		PASGT +LCE	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Movements												
Armhole Size	8	0	11	5	12	11	11	0	15	1	3	4
Bulk	2	0	22	9	25	13	17	22	25	21	27	33
Chest Fit	4	0	0	0	4	1	5	0	0	0	0	0
Chest Flexibility	0	0	8	5	6	8	0	3	5	8	17	6
Collar Fit	0	0	23	27	15	21	16	0	19	5	5	12
Collar Flexibility	3	0	27	33	21	25	6	2	20	20	8	11
Protruding Parts	0	0	1	11	1	14	34	36	15	27	27	21
Shoulder Width	8	0	17	28	11	30	0	11	13	22	9	24
Shoulder Flexibility	7	0	29	33	17	31	18	23	21	34	22	19
Stability	0	0	4	0	14	0	19	9	4	3	17	6
Ventilation	2	0	15	0	7	0	0	0	5	0	7	0
Waist Fit	0	0	0	0	4	0	16	7	11	0	0	0
Waist Flexibility	0	0	5	10	9	7	18	20	10	10	11	11
Weight	0	0	16	15	19	9	17	28	17	26	23	30
Tasks												
Armhole Size	10	5	14	9	10	10	12	0	13	10	4	4
Bulk	5	5	22	19	24	25	16	22	24	25	25	26
Chest Fit	4	0	5	2	0	0	4	0	3	2	6	0
Chest Flexibility	0	0	11	8	4	4	4	5	6	4	28	3
Collar Fit	1	0	18	19	18	12	8	7	12	6	5	7
Collar Flexibility	0	0	13	18	18	15	7	7	9	6	6	9

Table 12 (Continued)

Subjects' Summed Ratings of the Importance of Each Design Characteristic in Impairing Performance for Each Clothing Condition

Design Characteristics	Clothing Conditions											
	Utilities		STD B		PASGT		LCE		STD B +LCE		PASGT +LCE	
	Man	Woman	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Protruding Parts	2	0	0	11	6	16	24	41	22	22	21	27
Shoulder Width	0	0	18	26	12	21	2	12	14	31	10	29
Shoulder Flexibility	6	9	37	29	31	39	20	13	30	33	22	26
Stability	0	0	8	1	14	0	30	2	11	1	12	4
Ventilation	5	0	12	10	9	1	0	0	10	1	10	5
Waist Fit	4	0	0	0	1	0	13	8	1	0	3	0
Waist Flexibility	0	0	3	0	4	8	17	16	8	3	6	3
Weight	0	0	19	18	21	19	23	20	16	33	22	37

Table 13

Median Rating of the Importance of Each Design Characteristic
In Impairing Performance for Each Clothing Condition

Design Characteristic	Clothing Condition											
	Utilities		STD B		PASGT		LCE		STDB + LCE		PASGT + LCE	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Armhole Size	1.36	1.25	2.75	2.83	2.00	2.50	1.36	1.05	3.00	3.00	2.00	2.17
Bulk	1.25	1.17	3.75	3.10	3.30	3.50	3.33	3.83	3.50	4.30	3.93	4.13
Chest Fit	1.25	1.10	2.30	2.00	2.30	1.70	1.75	1.25	2.10	2.17	2.21	2.00
Chest Flexibility	1.25	1.10	2.50	2.17	2.50	2.00	2.00	1.36	2.70	2.30	2.83	2.07
Collar Fit	1.17	1.05	3.30	4.17	2.75	3.17	2.50	1.25	3.17	3.36	2.36	3.10
Collar Flexibility	1.17	1.05	3.30	3.93	3.00	3.00	3.00	1.17	3.50	3.50	2.70	3.17
Protruding Parts	1.17	1.00	2.00	1.50	1.90	1.83	4.17	3.50	3.50	4.64	4.50	4.50
Shoulder Width	1.36	1.10	3.50	4.50	2.75	3.50	2.83	2.17	3.67	4.50	3.50	4.00
Shoulder Flexibility	1.25	1.17	4.07	4.50	3.21	4.17	2.83	3.50	4.64	4.64	3.50	4.25
Stability	1.17	1.10	2.25	1.50	2.00	1.50	2.83	2.30	2.75	2.07	2.90	2.25
Ventilation	1.25	1.10	3.17	2.90	2.17	2.00	1.25	1.10	2.70	1.75	2.50	2.50
Waist Fit	1.25	1.17	1.83	1.50	1.83	1.50	2.88	2.00	2.00	1.50	1.90	1.90
Waist Flexibility	1.17	1.10	2.50	1.75	2.30	2.50	3.25	2.50	2.83	2.25	2.70	2.50
Weight	1.10	1.10	3.30	4.10	3.50	3.17	3.17	4.17	4.10	4.90	3.50	4.64

Table 14

Median Rating of the Importance of Each Design Characteristic in Aiding Performence for Each Clothing Condition

Design Characteristic	Clothing Condition											
	Utilities		STD B		PASGT		LCE		STDB + LCE		PASGT + LCE	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Armhole Size	4.50	3.83	3.00	3.50	4.10	2.83	4.64	4.25	2.50	2.10	4.00	2.83
Bulk	4.50	3.00	2.00	1.36	1.90	1.36	1.83	1.50	1.90	1.10	1.75	1.10
Chest Fit	4.10	4.00	3.00	2.50	2.70	2.90	2.17	3.10	2.67	2.75	2.83	3.00
Chest Flexibility	4.50	4.50	2.50	2.50	2.33	3.00	2.25	2.83	2.30	2.50	2.83	3.25
Collar Fit	4.64	4.00	1.50	1.36	2.33	1.50	2.25	2.75	2.00	1.75	2.83	2.17
Collar Flexibility	4.50	4.17	1.83	1.17	2.25	1.36	2.17	2.50	2.50	2.00	2.50	1.83
Protruding Parts	4.00	3.00	1.83	1.17	2.50	1.36	1.36	1.25	1.36	1.10	1.36	1.25
Shoulder Width	4.50	4.17	2.50	1.25	2.50	1.50	2.50	2.00	1.90	1.36	2.83	1.50
Shoulder Flexibility	4.17	4.17	1.50	1.25	2.17	1.36	1.75	2.50	1.36	1.25	2.25	1.36
Stability	3.50	3.00	3.07	3.00	3.17	2.30	1.83	2.50	3.00	2.17	2.50	2.50
Ventilation	4.17	3.50	1.50	1.75	2.83	2.17	3.50	2.75	1.90	1.75	2.50	1.83
Waist Fit	4.00	4.17	3.00	2.25	3.17	1.90	2.33	2.00	3.00	2.00	3.67	1.88
Waist Flexibility	4.50	4.50	2.50	2.00	2.83	1.50	2.00	1.50	2.75	1.83	3.00	1.50
Weight	4.75	4.64	2.17	1.36	2.50	1.50	2.75	1.50	2.00	1.10	1.83	1.10

while the STD B vest plus LCE condition received the men's highest median rating for weight. Both the men and the women gave the highest impairment ratings for shoulder flexibility to the condition in which the LCE was used with the STD B vest. They also indicated that the greatest performance impairment attributable to the design characteristic of shoulder width occurred with the STD B vest and LCE combination. For those conditions in which the LCE was used alone or with the armor, protruding parts were rated as being between moderately to extremely important in impairing performance (Table 13).

The impairment ratings of the men and the women were contrasted by applying the Kolmogorov-Smirnov two-sample test in order to determine whether the ratings given to each clothing condition within each design characteristic varied as a function of the sex of the participants. It was found that the women gave a significantly higher impairment rating ($p<.05$) to the shoulder flexibility of the STD B vest when it was worn alone than the men did. The men rated the LCE, when it was worn alone, significantly higher ($p<.05$) than the women did in terms of the performance impairment attributable to the design characteristic of collar fit and flexibility and waist fit. There were no other significant differences between the men and the women in the impairment ratings assigned.

The Kolmogorov-Smirnov two-sample test was also applied to the ratings given to the design characteristics in terms of aiding performance. The men gave a significantly higher rating ($p<.05$) to the bulk and the weight of the STD B vest plus LCE combination and to the waist fit of the LCE worn with the PASGT vest than the women did. There were no other significant differences in the ratings as a function of the sex of the participants. As was the case for the previous question, the most positive ratings were given to the condition in which the utilities were worn alone. There was also a tendency for the two STD B vest conditions to be rated lower for aiding performance than the comparable PASGT vest conditions (Table 14).

The results of Question 3 in Section II are presented in Table 15. Median ratings were obtained as they had been for the previous two questions. Bulk, weight, and obstructions were judged by the women to be problems of considerable to extreme importance in impairing performance when either type of armor was worn with the LCE. The median ratings given by the men to these three problems areas were slightly lower. The Kolmogorov-Smirnov two-sample tests indicated two significant differences between the ratings given by the men and the women. The men rated the PASGT vest, when it was worn without the LCE, significantly higher ($p<.05$) than the women did with regard to slipping. The women rated the bulk of the PASGT vest plus LCE combination significantly higher ($p<.05$) than the men did.

Median ratings of the adjectives presented in Section III of the questionnaire (Appendix D) were obtained by assigning a numerical value to each point on the seven-point scale. The extremely negative category was assigned a value of "1", the neutral category a value of "4", and the extremely positive category a value of "7". The median ratings are presented in Table 16. The median ratings ranged from slightly below the very negative to slightly below the extremely positive points on the scale.

Table 15

Median Rating of the Importance of Problem Areas in Impairing Performance for Each Clothing Condition

	Clothing Condition											
	Utilities		STD B		PASGT		LCE		STD B + LCE		PASGT + LGE	
Problem	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Bulky	1.17	1.17	3.64	3.00	3.70	3.13	3.25	4.50	4.00	4.50	4.06	4.17
Chaffing	1.10	1.17	2.83	3.70	2.00	2.10	2.50	2.17	3.00	3.17	2.70	2.50
Digging In	1.10	1.10	2.70	2.83	2.17	2.07	3.75	3.75	2.75	3.25	2.33	3.75
Heavy	1.05	1.10	3.50	3.83	3.50	2.36	3.50	3.50	4.25	4.90	3.50	4.64
Hot	1.05	1.10	3.17	3.00	2.83	2.50	1.25	1.25	3.50	3.30	3.00	3.30
Loose	1.25	2.50	1.50	1.17	1.75	1.17	1.36	1.36	1.70	1.36	1.83	1.25
Obstructions	1.25	1.17	2.30	1.36	2.50	2.17	3.50	4.64	3.75	4.50	3.70	4.64
Pressure	1.05	1.10	1.75	3.64	2.00	2.25	1.83	3.75	2.50	3.75	2.30	3.75
Pinching	1.17	1.10	2.17	1.75	1.75	1.17	2.75	2.00	2.50	1.70	2.00	2.00
Slipping	1.10	1.10	1.36	1.25	1.90	1.05	2.17	1.36	1.83	2.07	1.67	1.50
Tight	1.10	1.17	1.36	1.25	1.75	1.25	1.75	1.17	1.83	2.50	1.90	1.25
Unbalanced	1.10	1.10	2.00	1.17	2.00	1.25	3.83	1.90	3.50	2.50	3.50	1.83

Table 16

Median Rating of Bipolar Adjectives for Each Clothing Condition

Adjective Dimension	Utilities		STD B		PASGT		LCE		STDB + LCE		PASGT + LCE	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Comfort	6.75	6.30	3.17	3.17	3.50	3.50	3.50	4.70	2.50	2.25	3.83	2.33
Flexibility	6.76	6.17	3.25	2.75	4.60	4.00	4.00	4.75	3.00	1.70	3.60	2.36
Ventilation	5.25	5.90	3.50	3.17	4.00	4.10	5.50	6.17	2.90	3.10	3.50	3.00
Weight	6.83	6.50	3.00	3.07	3.50	3.33	3.25	3.00	2.75	1.75	2.75	1.70
Balance	6.50	5.17	4.17	5.10	4.30	5.00	3.10	4.83	3.50	4.10	4.00	4.25
Fit	6.50	5.76	4.75	4.70	5.60	4.90	4.64	6.00	4.70	3.83	5.50	4.10
Stability	6.64	5.00	4.25	4.50	5.50	4.30	4.25	4.50	4.17	4.36	4.50	4.30
Restriction	5.83	5.30	3.75	4.00	6.17	3.07	3.50	4.50	3.30	2.90	4.76	2.60
Liking	6.75	6.07	3.50	3.33	5.17	4.50	4.00	4.60	2.83	2.60	4.93	2.50

The men rated the utilities most favorably on every adjective with the median ratings being between the very and the extremely positive points on the scale. The women also gave the highest ratings to the utilities on every adjective except two – fit and ventilation. Here, they rated the LCE somewhat more positively. The Kolmogorov-Smirnov two-sample test was applied to each clothing condition and adjective dimension to determine whether the ratings assigned varied as a function of the sex of the participants. It was found that women gave the PASGT vest a significantly more negative rating ($p<.05$) than the men did on the restriction dimension. The women's median rating indicated that they found the vest to be somewhat binding while the men rated it as somewhat free-moving. The men and the women also differed significantly ($p<.05$) in the ratings of the fit of the LCE. The median rating given by the men was between neutral and somewhat well-fitted, while the women rated the LCE, when it was used without the armor, as being very well fitted. A third significant difference ($p<.05$) obtained between the ratings given by the men and the women was in the degree of liking expressed for the PASGT vest and LCE combination. The men gave this condition a significantly higher rating than the women did.

In comparing the median ratings given to the two types of body armor as a function of the presence or absence of the LCE, it can be seen in Table 16 that the ratings on the various adjective dimensions were generally more positive when the armor was worn without the LCE than when the LCE was used in combination with the vests. The median ratings given by the men to the STD B vest worn alone were more negative than those given to the PASGT vest worn alone. The same relationship was found among the median ratings when the vests were used with the LCE, with the exception of the weight dimension. Here, the men gave equal median ratings to both types of vest. The women also gave lower ratings to the STD B than to the PASGT vest when the LCE was not worn, with the exception of the balance, the stability, and the restriction dimensions. In these instances, the median ratings for the STD B vest were somewhat higher than those for the PASGT. For the two conditions in which the LCE was worn with the armor vest, the women's median ratings given to the STD B armor were equal to or somewhat higher than those given to the PASGT vest on the ventilation, the weight, the stability, the restriction, and the like dimensions.

In order to determine whether or not the ratings given to the bipolar adjectives differed significantly as a function of clothing condition, the Friedman two-way analysis of variance by ranks (χ_r^2) was applied to the data. Separate analyses were performed on the men's and the women's data for each adjective dimension. For the Friedman tests, the ratings given to the clothing conditions by each subject were ranked and these ranks served as the raw data for the analyses. The first set of analyses done included all six clothing conditions. It was found that the scores given on all adjective dimensions by the men and the women varied significantly as a function of the clothing condition being rated with one exception: The ratings given by the women to the stability dimension did not differ significantly, $\chi_r^2(5)=2.26$.

Because the clothing condition in which utilities alone were worn received the most favorable ratings from both the men and the women on most adjective dimensions, a second set of Friedman tests was performed in which the utilities condition was excluded. The results of these analyses are presented in Table 17. For the men's data, the only significant differences were obtained on the ventilation, the stability, the restriction, and the liking dimensions. The most positive ventilation ratings were received by the LCE condition, while the highest ratings

Table 17

Results of Friedman Tests Performed on Bipolar Adjective Ratings

Adjective Dimension	Sex	χ^2_r	p
Comfort	Men	7.67	N.S.
	Women	17.65	.01
Flexibility	Men	6.57	N.S.
	Women	17.92	.01
Ventilation	Men	22.82	.001
	Women	15.97	.01
Weight	Men	7.38	N.S.
	Women	18.27	.01
Balance	Men	9.40	N.S.
	Women	4.83	N.S.
Fit	Men	8.33	N.S.
	Women	6.17	N.S.
Stability	Men	11.82	.02
	Women	1.10	N.S.
Restriction	Men	11.88	.02
	Women	13.55	.01
Liking	Men	11.38	.05
	Women	14.83	.01

on the other three dimensions were given to the PASGT vest. In the analyses performed on the women's data, no significant differences were obtained on the stability, the balance, or the fit dimensions. However, the ratings given to the other bipolar adjectives still differed significantly as a function of clothing condition. The PASGT vest, when it was worn without the LCE, was given the highest median rating on the weight dimension. The LCE alone received the highest ratings on the comfort, the flexibility, the ventilation, and the restriction dimensions. The PASGT vest alone and the LCE alone received equally high ratings on the liking dimension. The STD B vest and LCE combination was generally rated lowest.

DISCUSSION

The Influence of Body Armor and Load-Carrying Equipment on Performance

Both types of body armor were tested with and without the LCE although, in a field situation, the vests would probably always be worn with at least some components of the fighting load. This was done in order to acquire information pertaining to the effects on performance attributable to the armor, *per se*, versus the effects of the interaction between the armor and the LCE. In examining the impact of the armor and the LCE, the results of the raw score analyses performed on the task data will be considered, rather than the results of the percentage score analyses. Since the former included the utilities worn alone as a level of the clothing variable, the relationship between this condition of minimal encumbrance and those involving armor and LCE can thereby be considered.

With the exception of Upper Leg Forward Extension and the O'Connor Finger Dexterity Test, performance on all tasks in the battery was significantly affected by the clothing variable. In general, the performance levels on these tasks were highest when the utilities were worn without any additional items and lowest when the STD B armor vest was worn in conjunction with the LCE. However, as was found in the Bensel and Lockhart study (reference 2) of body armor and load-carrying equipment, the specific impact of adding either armor, LCE, or both to the utilities varied as a function of the body part involved in the task. There were significant differences between the scores obtained with the PASGT and the STD B vests on four of the tests for which a clothing effect was found; better performance was achieved with the PASGT vest in each of these instances.

Scores on both flexibility tasks involving head movements, Ventral-Dorsal Head Flexion and Head Rotation, were significantly better with the PASGT than with the STD B vest when the LCE was not used. On the Head Rotation Task, the scores achieved with the PASGT vest were also significantly better than those achieved with the STD B even when the LCE was worn in conjunction with the armor. Thus, it appears that the combination of the LCE with the vests had a more potent effect on Head Flexion than it did on Head Rotation. The yoke of the LCE suspenders, located at the back of the subject's neck, pressed against the base of the collar on the armor. The suspenders also impinged upon the collar around the lateral surface of the neck toward the subject's back. This collar-suspender interaction probably restricted dorsal head flexion because, in moving the head in this direction, the subject was pushing not only against the collar, but against the LCE suspenders as well. While rotating the head, the subject's lower jaw touched the front sides of the collar, an area which the suspenders did not contact.

As Bensel and Lockhart (reference 2) also found, the presence of armor was the principal factor in limiting the extent of both head movements relative to those achieved with the utilities alone, even though the LCE did interact somewhat with the armor to affect performance. Scores for both vests were significantly lower than those for the utilities, while those for the LCE alone were not. Also, the addition of the LCE to either vest did not lower performance levels significantly relative to the levels achieved when either vest was worn without the LCE. The restriction of head movements imposed by the armor vests is attributable to their stand-up collars. The greater limitation of movement with the STD B armor is, most likely, due to dimensional and material differences between the vests. Although the STD B vest has a larger neck opening than the PASGT vest, it also has a thicker, slightly higher, and more rigid collar. The questionnaire responses indicated that the test participants were aware of the restriction on head movements imposed by the STD B armor and the minimal effect of the LCE on performance.

The other two tasks in the battery which yielded significant differences between the PASGT and the STD B vests were Upper Arm Abduction and Forward Extension. In both instances, superior scores were achieved with the PASGT vest whether or not the LCE was used. However, significant differences in scores for the two vests were obtained only when the LCE was worn with the armor. On Upper Arm Abduction, performance with STD B vest and LCE combination was significantly worse than performance under all other clothing conditions, and the Upper Arm Forward Extension scores achieved with the STD B vest plus the LCE were significantly lower than all others except those achieved when the STD B armor was worn alone.

Upper Arm Abduction required the raising of both arms in the body's frontal plane and Upper Arm Forward Extension required the raising of one arm in the body's sagittal plane. On the body itself, the arm-shoulder complex of joints is the origin of the angle generated as the arm is abducted or extended forward. In this study, the upper torso was clothed in armor or LCE made of fabrics having limited extensibility. Therefore, the relationship of these items to the body must be taken into consideration in assessing the differences in performance as a function of the type of armor vest worn.

It appears that shoulder length was the principal dimensional characteristic of the armor which affected performance on these tasks. As the vertical plane of the vest's armhole opening is moved out from the body's vertical plane, which occurs as the shoulder is lengthened, abduction and forward extension at the body's arm-shoulder joint are increasingly restricted because the armhole opening, a part of the armor vest's joint for these movements, then extends over and beyond the body's arm-shoulder joint area.

Measurements of the armor indicated that the shoulder length of the STD B vest is between 2.1 and 3.1 cm (.8 and 1.2 in.) greater than that of the PASGT, depending upon the size of the vest measured. The assessments of armor fit indicated that the shoulder portion of the STD B vest extended beyond the acromion on 17 of the 24 participants in this study. The PASGT vest extended beyond this point to a lesser extent on 12 of the participants. Based upon these armor dimensions and fit ratings, as well as the subjects' questionnaire responses, it appears that shoulder length was indeed a factor which resulted in Upper Arm Abduction and Forward Extension scores for the PASGT vest being superior to those for the STD B.

Because there was a significant difference in performance between the two vests only when the LCE was also worn, another aspect of the armor should be considered which is related to garment design rather than to garment dimensions. This is the ease with which the armor vests and the LCE move on the upper torso as the arms are raised. For example, the suspenders of the LCE do not extend out to the arm-shoulder joint. However, the LCE can be expected to limit the degree to which the arms can be abducted or extended because the LCE belt is weighted with equipment and is secured around the waist. Therefore, in raising the arms while wearing the LCE, one has to overcome the restriction imposed by the belt. With regard to design of the armor, the PASGT vest has what are referred to as articulating shoulder pads. The main portion or body of the PASGT vest does not extend over the shoulders. Instead, pads of ballistic material, sewn to the vest at the base of the neck, form the shoulders of the garment and are further secured to the vest via elastic webbing and snaps. The shoulders of the STD B vest, on the other hand, are not separated in any way from the rest of the garment. When the arms are raised while the PASGT vest is being worn, the shoulder pads lift up with the arm movement and, after the limits of extensibility of the elasticized webbing have been reached, the rest of the vest is raised. To raise the arms while wearing the STD B vest, the entire garment must move up with the arm movement.

It should be more difficult for the armor to move in consonance with the arm when the LCE is worn over the armor than when the armor is worn alone. However, the shoulder design of the PASGT vest permits the raising of the arms with only minimal movement of the rest of the vest and the LCE, while the STD B vest does not. The subjects' ratings on the questionnaire with regard to the design characteristic of shoulder flexibility indicated that they also perceived movement to be easier with the PASGT vest. In summary, the shorter length of the shoulder and the articulating shoulder pad design of the PASGT vest are probably the factors which accounted for superior performance with this vest on the Upper Arm Abduction and Forward Extension tasks.

Upper Arm Backward Extension, the third arm-shoulder flexibility task included in the performance battery, was significantly affected by the clothing variable, but no significant differences between the two armor vests were obtained. The highest score was achieved when the utilities were worn alone and this score was significantly better than the lowest score, which occurred when the STD B vest was used. The backward extension of the arm, like Upper Arm Forward Extension, was a movement in the body's sagittal plane. However, unlike either abduction or forward extension, the direction of the movement was such that the arm could not approach the vertical as it was extended backward. Therefore, shoulder length and the ease of garment movement would not be expected to impact upon Upper Arm Backward Extension, but crossback length would be. As crossback length is increased, the vertical plane of the vest's armhole opening is moved out from the body's vertical plane, the same phenomenon which occurs as shoulder length is increased. The crossback length of the STD B vest was between 6.8 and 10.0 cm (2.7 and 3.9 in.) longer than that of the PASGT vest. Also, the crossback dimension of the STD B vest was judged to be too long on 18 of the 24 subjects; the PASGT vest was found to be too long on 11 of the subjects. These dimensional and fit differences between the vests were great enough to result in performance with the STD B being significantly worse than that with utilities alone, while performance with the PASGT vest was not.

If crossback length was the factor which affected backward extension of the arm, it would be expected that the use of the LCE in combination with the STD B vest would also result in a score significantly lower than the score for utilities alone, but this was not the case. This appears to be due to the fact that the test participants could not perform the task properly when they used the LCE because the location of the canteen on the belt prevented straight arm movement. Instead, the participants moved the arm back and out from the body at an angle and thus avoided any interference posed by the vest at the back of the shoulder and upper arm.

In addition to the upper arm flexibility tasks, rate of movement, psychomotor coordination, and manual dexterity tasks included in the battery also involved arm-shoulder movements. Performance on some of these was affected by the clothing variable although there were no significant differences in performance between either of the STD B vest conditions and the respective PASGT vest conditions. On the Ball-Pipe Test, a measure of rate of movement, the best score, which was achieved with the utilities alone, was not significantly higher than the score for the PASGT vest or the LCE conditions. Scores for these last two conditions were not significantly better than the next lowest scores, those for the STD B vest alone or the PASGT vest and LCE combination, but they did differ significantly from the lowest score, which was achieved when the STD B vest was worn with the LCE. There were no significant differences in performance among the STD B armor condition or the two armor and LCE combinations.

The arm movement required in performing the Ball-Pipe Test was in the body's sagittal plane, the same plane in which the arm was moved on the Upper Arm Forward Extension task. The Ball-Pipe Test did not require maximum displacement of the straight arm from the torso like Upper Arm Forward Extension or Abduction did since the subjects had to reach only 14.50 cm (5.7 in.) above their heads to drop the ball into the pipe. However, the amount of upper arm movement was still great enough for the speed with which the Ball-Pipe Test could be performed to be affected by the same factors which impacted upon Upper Arm Forward Extension and Abduction; that is, the shoulder design of the armor and the ease of movement of the armor and the LCE on the upper torso. Therefore, although there were no significant differences between the two types of armor, performance with the PASGT vest was somewhat superior to performance with the STD B vest. Because of possible fatigue induced by the continual raising of the arm required on the Ball-Pipe Test, the weight of the items suspended from the shoulders is an additional parameter to consider in assessing task performance. The scores decreased as the weight on the torso was increased with the exception of the conditions involving the LCE alone and the STD B vest alone; the subjects achieved a somewhat higher score with the heavier LCE than they did with the lighter STD B vest. This reversal could well be attributable to the restraints placed upon movement by the shoulder design of the STD B vest.

On the Pursuit Rotor, a test of psychomotor coordination, the best score was achieved with the PASGT vest and the worst score was achieved with the STD B vest and LCE combination. These two scores differed significantly from each other, but there were no other significant differences among the clothing conditions. As was the case on the Ball-Pipe Test, the Pursuit Rotor did not require maximum displacement of the arm from the torso like the upper arm flexibility tasks did. Instead, a circular movement of the arm was required while

the lower arm was maintained in a horizontal position and the upper arm was abducted slightly from the torso. It would seem that excessive crossback length of the armor as well as protruding items on the LCE belt would interfere with the smooth and regular arm movements needed to successfully track the target on this task. This appears to have been the case since not only did the STD B vest plus the LCE result in the poorest score, but the two lowest scores were achieved when the LCE was worn with either type of body armor.

One of the two manual dexterity tests included in the performance battery, the Bennett Hand Tool Dexterity Test, was significantly affected by the clothing variable. The best score, which was achieved when the utilities were worn alone, was significantly superior to the worst score, which was achieved when the LCE was used with the STD B vest. As was the case on the Pursuit Rotor, the excessive crossback length of the STD B armor probably interfered with the freedom of arm movement necessary in performing this task. In addition, the bulk of the items on the equipment belt prohibited the subjects from positioning themselves as close to the work area as they could when the LCE was not used. This is perhaps the reason that the lowest performance levels were obtained when the LCE was being worn. The clothing variable did not affect performance on the O'Connor Finger Dexterity Test, the other manual task in the battery. Unlike the Bennett, the O'Connor required movements of the lower arm at the elbow with little upper arm and shoulder involvement. The movements were short, repetitive displacements of one arm and hand in the body's transverse plane. Therefore, the nature of the O'Connor Test was such that armhole opening characteristics had minimal impact on performance. The subjects could assume a body posture and maintain it for the duration of a trial, which they could not do while performing the Bennett Test. Therefore, effects of the presence of the LCE was minimal.

In addition to performance of various arm-shoulder and head-neck movements, performance on tasks requiring flexion at the waist in the body's sagittal plane was also significantly affected by the clothing variable although no differences between the armor vests were obtained. On the two waist flexibility tasks, Standing and Sitting Trunk Flexion, the mean score achieved with the utilities alone was best, but it was not significantly better than those obtained when either type of armor vest or the LCE were worn alone. The poorest performance on both tasks occurred when the LCE was used in conjunction with either vest. These worst scores differed from the score for the utilities alone. On Standing Trunk Flexion, the lowest score, that for the STD B vest plus LCE condition, was also significantly lower than the scores obtained when either vest or the LCE were worn alone. It would seem that increasing bulk or rigidity in the waist area, as represented by the materials comprising the vests and the equipment belt components of the LCE, would decrease the amount of flexion possible in that region. The results for the Standing and the Sitting Trunk Flexion tasks indicate that this was the case, although the decrease in flexion was gradual as these items were added to the body.

One of the rate of movement tasks included in the present battery, the Figure-8 Run and Duck Test, involved flexion at the waist, as well as the speed of movement component. It appears that, in addition to bulk or rigidity at the waist, there was another factor affecting performance on this task that did not affect the trunk flexion tasks since the use of either vest or the LCE resulted in scores which were significantly lower than those achieved when only utilities were worn. There was also a further significant decrement in the scores when the LCE was used in conjunction with the vests. The weight of the items on the torso would

seem to be a factor in determining the speed with which this task could be performed, as it was on the Ball-Pipe Test. Indeed, speed did decrease as the weight of the items on the torso was increased.

The failure of the waist flexion tasks to discriminate between the two types of armor vests indicates that differences in designs, dimensions, and materials were not potent enough to yield differences in performance. The fact that the LCE with its ammunition cases and other bulky, protruding, and rigid items did not restrict bending at the waist to a significantly greater extent than did the armor vests leads to the conclusion that more extreme differences between the vests would be required in order for performance on waist flexion tasks to be differentially affected by the type of armor worn. It is interesting to note that the impairment ratings given to waist fit and flexion were relatively low when compared to ratings given to other design characteristics and did not reflect differences between the two types of armor.

Another group of tasks in the performance battery required movement of the leg from the hip. These tasks were included in the study in order to determine whether or not the length and rigidity of the vests or the bulk, rigidity, and protrusions of the LCE would limit leg movement. Performance of two of the three leg flexibility tasks was significantly affected by the clothing variable. These were Upper Leg Flexion and Abduction. As was the case with tasks involving waist flexion, there were no significant differences in scores as a function of the type of body armor being worn. The task which was not affected by the clothing conditions was Upper Leg Forward Extension. It required that the leg be kept straight at the knee and thrust forward in the body's sagittal plane. Upper Leg Flexion involved movement in the same body plane, but the leg was bent at the knee and the upper leg was raised toward the chest as far as possible. Therefore, depending upon the extent to which the upper leg was moved, it could come into contact with the lower edge of the vests and the LCE, which was not the case when the leg was extended forward. The highest mean score on Upper Leg Flexion, which was achieved when the utilities were worn alone, was significantly better than the lowest score, that which occurred when the LCE was worn with the STD B vest. There were no other significant differences among the clothing conditions. Thus, there were no clear-cut performance differences on Upper Leg Flexion as a function of the presence or absence of the armor or the LCE. It is possible that the vest and the LCE were pushed up as the leg was raised and, therefore, did not act to restrict flexion of the upper leg. On Upper Leg Abduction, on the other hand, there were more extensive differences among the clothing conditions. Use of either vest or the LCE alone resulted in mean scores which were not significantly lower than that achieved when the utilities were worn alone. However, the addition of the LCE to the PASGT vest did lower the performance level significantly relative to that attained with the utilities. When the LCE was used with the STD B vest, the mean score was significantly lower than the score for the utilities alone as well as that for the LCE alone. Upper Leg Abduction required a raising of the leg in the body's frontal plane with the leg being kept straight at the knee. The length and rigidity of the vests and the LCE would be expected to affect performance of this task insofar as these items extended over the lateral surface of the upper leg. Based upon the analysis of this task, it appears that it was easier to move the leg against the restriction of the vests and the LCE when these items were worn separately rather than in combination.

The Railwalk, one of the psychomotor coordination tasks included in the battery, also required leg movements and was significantly affected by the clothing conditions tested. In the Bensel and Lockhart (reference 2) study, performance on this task was unaffected by the use of armor vests or load-carrying equipment. However, in the present experiment, the subjects practiced the Railwalk prior to the initiation of the data-collection sessions while the subjects in the Bensel and Lockhart study did not. Therefore, it appears that subjects must be trained on this task until consistent scores are achieved if performance level is to be sensitive to clothing effects. As was found on Upper Leg Flexion, there was a significant difference between the highest Railwalk score, achieved when the utilities were worn alone, and the lowest score, achieved with the PASGT vest and LCE combination. There were no other significant differences among the clothing conditions. The results of the Railwalk, as well as the flexibility tests involving leg movements, indicate that performance on such tasks was affected by the use of the armor vests and the LCE, particularly when these items were worn together. However, as was the case on the waist flexion tasks, the decrease in leg movement capabilities was gradual as these items were added to the body.

Considering the overall results of the task battery and the questionnaire, it appears that the collar and the shoulder designs of the PASGT vest offer definite advantages in terms of body movement capabilities over the design of the STD B armor. It is important to note that there were significant differences in performance on some tasks as a function of the type of vest worn even when the LCE was used with the vests. There were also a number of tasks in the battery on which, although performance did not differ significantly as a function of the type of vest worn, the scores achieved with the STD B armor were inferior to those achieved with the PASGT vest. This finding further substantiates the desirability of the PASGT vest over the STD B. In a field situation, it is probable that the armor and the LCE would be worn for much longer periods of time and under much higher levels of physical activity than were required in the present experiment. Under these conditions, even the small advantages provided by the PASGT vest which were identified in this study may be expected to increase in importance and to impact positively on mission performance. Another very important consideration in assessing the relative merits of the two types of armor is the user's opinion. The participants in this study generally preferred the PASGT to the STD B vest and, in addition, indicated the importance of bulk and weight in impairing performance regardless of the particular clothing condition being tested. It appears that the subjects found the vests and the LCE to be burdensome, but felt that the PASGT vest imposed fewer restraints on body movement capabilities than the STD B vest did.

The Influence of Sex on Performance

One of the considerations in the present study was to determine the acceptability of the body armor and the load-carrying equipment for use by women, as well as by men. Of particular concern was whether or not the fit of the vests, which was found to be less acceptable on the women than on the men, would contribute toward greater impairment of the women's performance than of the men's. The results of both the raw score and the percentage score analyses will be considered in the examination of the effects of the sex of the subjects. A significant effect of sex obtained from a raw score analysis would indicate a difference between the men and the women when all clothing conditions, including the utilities alone, are considered. Therefore, a difference between the raw scores of the men and the women may

reflect a difference in their basic abilities to perform a certain task, rather than effects attributable to the armor and the LCE. In obtaining the percentage scores, the raw score achieved by each subject while wearing the utilities alone was used as a baseline score and set equal to 100%. The remaining scores for each subject were expressed as percentages of this baseline. The purpose of this data transformation was to obviate differences between the performance levels of the men and the women which were not a function of the LCE or the armor vests used in this study.

The raw score analyses revealed that performance levels on six tasks were significantly affected by the sex of the subjects. Over all clothing conditions, the men were 12.0% faster than the women in completing the Figure-8 Run and Duck Test. The men progressed 26.4% further on the Railwalk than the women did. The difference between the sexes on this task is probably attributable in part to differences in foot length since the score was the distance walked on the rail in heel-to-toe fashion. Both manual dexterity tests included in the performance battery were also significantly affected by the sex of the participants. On the O'Connor Finger Dexterity Test, which required fine finger movements, the women took 17.9% less time to complete the task than the men did. The Bennett Hand Tool Dexterity Test involved gross movements of the whole hand and wrist. The men's time to task completion was 11.1% faster than the women's. There was no significant sex effect on the Ball-Pipe Test. However, there was a significant interaction between the clothing and the sex variables which was attributable to a different ordering of the scores for the men and the women. The women's lowest scores occurred when the LCE was worn with either vest and the men's scores were lowest under the two STD B vest conditions.

Upper Arm Forward Extension was another task which yielded a significant interaction. Here, the men performed better while wearing the PASGT vest alone than they did with the LCE alone; the opposite was true for the women. A significant main effect of sex was also obtained in the raw score analyses of both Upper Arm Forward Extension and Abduction. The men's score on the latter, over all clothing conditions, excelled that for the women by 14.4%, while the men's score on Upper Arm Forward Extension was 9.6% better than the women's. These two flexibility tasks were the only tasks in the battery for which the sex effect was found to be significant in the analyses of the percentage scores. Also, the only significant interaction between the sex and the clothing variables obtained in the percentage score analyses occurred on Upper Arm Forward Extension. On both Upper Arm Abduction and Forward Extension, the men's overall percentage scores relative to their utilities alone condition (85% on Upper Arm Abduction and 90% on Upper Arm Forward Extension) were significantly higher than the women's overall percentage scores relative to their utilities alone condition (77% on Upper Arm Abduction and 84% on Upper Arm Forward Extension). Therefore, the armor vests and the LCE had a greater impact on the women's performance of these two tasks than it did on the men's.

When the LCE or the PASGT vest was worn alone, the women's mean percentage scores on Upper Arm Abduction were approximately 85% of their utilities' score and the men's were approximately 90% of their utilities' score. There was a greater decrement in the performance of both the men and the women on the remaining clothing conditions and the decreases in the women's scores were greater than the decreases in the men's scores. The men's mean percentage scores on the remaining conditions ranged from a high of 86% for the STD B vest

alone to a low of 76% for the STD B vest plus the LCE combination. When the LCE was worn with the PASGT vest, the men's mean percentage score was 84% of the score with the utilities alone. The women's mean percentage scores were 76% for the STD B vest alone, 74% for the PASGT vest plus the LCE, and 63% for the STD B vest plus the LCE. Therefore, the significant effect of sex on Upper Arm Abduction was mainly attributable to differences in performance of the men and the women when the STD B vest was used with or without the LCE and the PASGT vest was used with the LCE. On Upper Arm Forward Extension, the impact of the PASGT vest and LCE combination on the scores of both the men and the women was not as great as it was on Upper Arm Abduction and the women's mean percentage score for this condition was only slightly lower than the men's. The greatest differences between the sexes occurred under the two STD B vest conditions. The significant interaction on Upper Arm Forward Extension was attributable to differences between the sexes for the PASGT vest alone and the LCE alone conditions. As was found in the raw score analysis of Upper Arm Forward Extension, the men performed better with the PASGT vest than with the LCE and the opposite was true for the women.

The importance of garment shoulder length and ease of movement in abducting and extending the arm forward has already been discussed and these factors appear to have contributed to the performance differences between the men and the women. The shoulder of the STD B vest extended beyond the acromion of all 12 of the women who participated in this study and five of the 12 men. The PASGT vest extended beyond this point, but to a lesser extent, on 10 of the women and two of the men. Therefore, the women encountered less arm movement restriction with the PASGT vest than they did with the STD B. However, as was indicated by the significant interaction on the Upper Arm Forward Extension task, the women were still at a disadvantage relative to the men whenever they were wearing either vest. The use of the LCE with the STD B armor magnified this disadvantage more than the use of the LCE with the PASGT vest did. The ease of movement due to the articulated shoulder design of the PASGT vest is probably the reason for this.

In addition to significant differences in performance of tasks in the battery as a function of the subject's sex, the men and the women also differed in some of their responses to the questionnaire. For example, the women gave significantly higher impairment ratings to the shoulder flexibility of the STD B vest and to the bulk of the PASGT vest and LCE combination than the men did. The women also rated the PASGT vest more negatively than the men did with regard to the amount of restriction it imposed. The men rated the PASGT vest and LCE combination higher with regard to the degree to which they liked these items than the women did. Both sexes generally rated the PASGT vest more favorably than they did the STD B, regardless of the presence or absence of the LCE. The differences between the ratings of the men and the women reflect the women's less positive responses toward both vests, particularly when they were used with the LCE. There are a number of possible reasons for the less positive opinions of the women including item fit and weight considerations.

Insofar as task battery performance was concerned, shoulder length was the only aspect of garment fit which could be identified as having a significant differential effect on the scores of the men and the women. However, both this factor and other aspects of the fit of the armor may have influenced the questionnaire data. For example, the fronts of both types of armor extended further below waist level on the women than they did on the men. As a result, on those occasions which required that subjects assume a seated position during performance of the task battery, the body armor road up off the shoulders of the women

to a greater extent than it did off the men's shoulders. This placed the neck opening of the armor further up on the women's necks than it was on the men's. Although this displacement of the armor did not result in significant differences between the sexes in performance of the head movements, it may have had a negative influence on the women's questionnaire responses.

With regard to weight, the small size of either vest plus the LCE was approximately 17% of the mean body weight of the women in this study, all of whom wore size small vests. The weight of these same items was approximately 15% of the mean body weight of the seven men who wore size small vests. It has been estimated thet, excluding footwear, overcoats, and miscellaneous items carried in pockets, the weight of the clothes that a civilian man would wear to the office on a normal spring day (2.08 kg) is approximately 1.5% greater than the weight that a women would wear under the same circumstances (.85 kg) and that approximately 30% of this can be accounted for by differences between the sexes in the body surface area to be clothed.[21] Thus, when the women wore the various combinations of armor and LCE during the course of the present study, they were not only bearing a greater weight per unit of body weight than the men were, but the women were also bearing items on the torso which represented a larger deviation from the weight of clothing they might normally wear than the men were. Therefore, although item weight did not appear to be a variable which differentially affected the performance of the men and the women on the task battery, weight, like fit, may have influenced the women's overall assessment of the vests to a greater extent than it did the men's.

Overview

It has been determined through this study that certain aspects of the PASGT vest, particularly collar and shoulder design, contribute to higher performance levels than those attained with the STD B armor on some tasks involving simple body movements. Differences in the performance of men and women have also been explored. In a laboratory experiment of this kind, the question arises as to the applicability of the findings to military situations. This, of course, is difficult to assess. However, the tasks comprising the battery were chosen as being representative of a broad range of basic human movements and, insofar as they were impaired by the armor and the LCE being tested, it may be inferred that similar movements would also be affected, regardless of the situation. On the other hand, it should be remembered that the tasks included in the battery did not require continuous, repetitive, whole-body movements over a prolonged period of time. Under such conditions, differences in performance as a function of the type of armor being worn and the sex of the wearer may be magnified.

CONCLUSIONS

The major findings of this study, based upon the overall results, are as follows:

1. In general, performance levels were highest when the utilities were worn without any additional items and lowest when the STD B vest was worn in conjunction with the LCE. Scores with the STD B vest and the LCE were from 7 to 31% lower than those with the utilities. The specific impact of adding either armor, LCE, or both to the utilities varied as a function of the body parts involved in the task.

[21] Denton, M. J. Fit, stretch, and comfort. **Textiles**, 1972, 1, 12–17.

2. The STD B armor impaired certain aspects of psychomotor performance, particularly head rotation and flexion and arm abduction and forward extension, to a greater extent than the PASGT vest did. The collar and shoulder designs seemed to be the critical features responsible for the superior performance with the PASGT vest.

3. Scores on six of the 16 tasks in the performance battery were significantly affected by the sex of the participants. After the data had been transformed to remove effects accounted for by differences in the basic capabilities of men and women, two tasks which required arm movements were found to be significantly affected by the sex variable. The men's performance excelled that of the women on both of these tasks. Excessive length of the armor across the women's shoulders appeared to be the fit characteristic which was responsible for impairing their arm movements relative to the men's.

4, Both the men and the women generally rated the PASGT vest more favorably than they did the STD B. However, the women's responses toward both vests were less positive than the men's were.

5. The principal impact of the LCE on task battery performance occurred on upper arm abduction movements and running and ducking in a figure-8 pattern. These findings appear to reflect the restraint imposed by the suspenders and the bulk and weight in the waist area attributable to the components on the belt of the LCE.

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APPENDIX A

Body Measurement Techniques

The techniques used to obtain the body dimensions of the subjects in this study were based upon those employed by White and Churchill (reference 18) in their anthropometric survey of US Army men and by Laubach, McConville, Churchill, and White[20] in their survey of US Army women. The equipment consisted of an anthropometer (Siber Hegner #101), a 2-meter steel tape (K&E Tip-Top Wyteface), a balance scale, and a china marking pencil. All subjects wore trousers and socks while measurements were taken. The men's upper torsos were bare and the women wore bras. The body measurements taken are described below.

Stature

The subject stands erect with heels together and head level. With the anthropometer in back of the subject, measure the vertical distance from the floor to the top of the head. The anthropometer arm firmly touches the scalp.

Waist Front Length

The subject stands erect with heels together, head level, and an elasticized tape around the waist at the level of the omphalion. With the steel tape, measure the surface distance from the suprasternale to the anterior waist at the level of the omphalion using the elasticized tape as the waist landmark.

Waist Back Length

The subject stands erect with heels together, head level, and an elasticized tape around the waist at the level of the omphalion. With the steel tape, measure the surface distance along the spine from the cervicale to the posterior waist at the level of the omphalion using the elasticized tape as the waist landmark.

Shoulder Length

The subject stands erect with heels together and head level. Mark the right acromion. With the steel tape, measure the surface distance along the top of the right shoulder from the base of the neck to the acromial landmark.

Sleeve Inseam

The subject stands erect with heels together and head level. The right arm is abducted slightly and the palm faces forward. With the steel tape, measure the distance from the top of the arm scye crease along the inner surface of the right arm to the ulnar side of the wrist

[20] Laubach, L.L., McConville, J.T., Churchill, E., & White, R.M. **Anthropometry of women of the US Army – 1977: Report No. 1 – Methodology and survey plan** (Tech. Rep. NATICK/TR–77/021). Natick, MA: US Army Natick Research and Development Command, June 1977.

crease. (The wrist crease is the deepest indentation on the arm adjacent to the palm.) The tape is held tense and does not follow the surface contour of the arm.

Sleeve Outseam

The subject stands erect with heels together and head level. The right arm is abducted slightly and the palm faces forward. Mark the right acromion. With the steel tape, measure the distance from the acromial landmark to the radial side of the wrist crease. The tape is held tense and does not follow the surface contour of the arm.

Sleeve Length

The subject stands erect with heels together and head level. The arms are held horizontally and bent at the elbows. The fists are pressed together in front of the subject. With the steel tape, measure the horizontal distance from the middle of the back along the outer surface of the right arm over the elbow to the ulnar side of the wrist crease.

Crotch Height

The subject stands erect with feet initially apart and then together after the anthropometer is in place. With the anthropometer in front of the subject, measure the vertical distance from the floor to the crotch. The anthropometer arm is firmly in contact with the highest point in the crotch. Add 1 cm to the reading for the width of the anthropometer blade.

Waist Height

The subject stands erect with heels together, head level, and an elasticized tape around the waist at the level of the omphalion. With the anthropometer to the right of the subject, measure the vertical distance from the floor to the anterior waist at the level of the omphalion using the elasticized tape as the waist landmark.

Neck Circumference

The subject stands erect with heels together and head level. With the steel tape, measure the circumference at the neck-shoulder intersection.

Shoulder Circumference

The subject stands erect with heels together, head level, and the arms hanging at the sides. With the steel tape in a horizontal plane, measure the shoulders at the level of the bulges of the deltoid muscles.

Arm Scye Circumference

The subject stands erect with heels together and head level. The right arm is initially raised and then lowered after the tape is in place. Mark the right acromion. With the steel tape passing through the axilla and over the right acromial landmark, measure the vertical circumference of the scye.

Chest Circumference at Scye

The subject stands erect with heels together, head level, and arms abducted slightly to allow passage of the tape between the arms and the trunk. With the steel tape passing through the axilla, measure the horizontal circumference.

Chest/Bust Circumference

The subject stands erect with heels together and head level. The arms are abducted slightly to allow passage of the tape between the arms and the trunk. With the steel tape, measure the horizontal circumference at the level of the nipples. The reading is made at the point of maximum quiet respiration.

Waist Circumference

The subject stands erect with heels together, head level, and an elasticized tape around the waist at the level of the omphalion. With the steel tape, measure the horizontal circumference of the trunk at the level of the omphalion using the elasticized tape as the waist landmark. The reading is made at the point of maximum quiet respiration.

Hip Circumference

The subject stands erect with heels together and head level. With the steel tape, measure the horizontal circumference of the hips at the level of the maximum posterior protrusion of the buttocks.

Intersaye Breadth

The subject stands erect with heels together and head level. With the steel tape, measure the horizontal distance across the surface of the back between the tops of the arm scye creases.

Natural Waist

The subject stands erect with heels together, head level, and an elasticized tape around the trunk at the level of the "natural waist". With the steel tape, measure the horizontal circumference of trunk at the level of the "natural waist" using the elasticized tape as the landmark. The reading is taken at the point of maximum quiet respiration.

Weight

Wearing the utility shirt and trousers, the subject stands on the scale platform. Weight is recorded to the nearest quarter pound and converted to kilograms.

APPENDIX B

Photographs of Clothing Conditions

Figure B1a. Front view of the men's and the women's utility shirt and trousers.

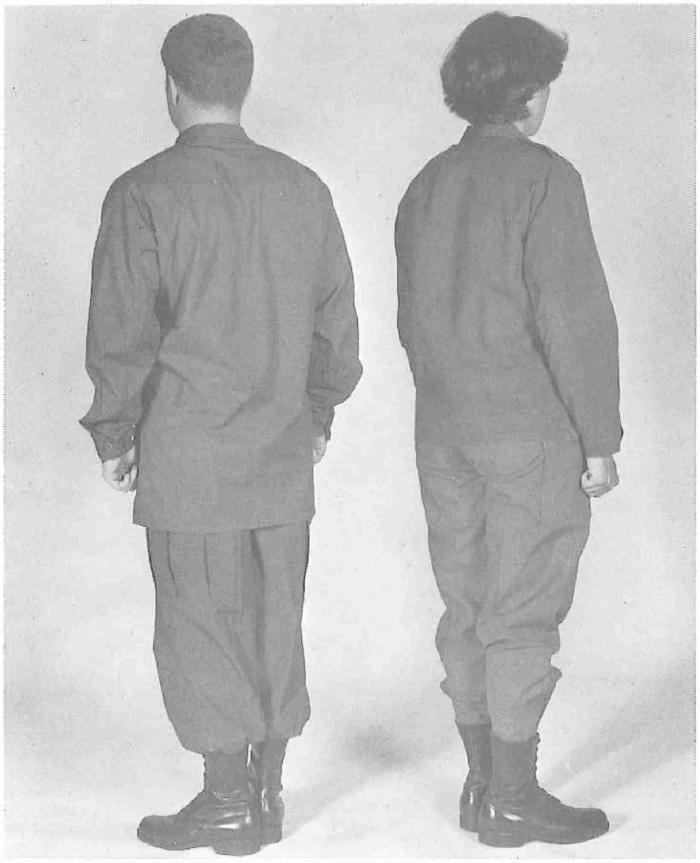

Figure B1b. Back view of the men's and the women's utility shirt and trousers.

Figure B2a. Front view of the STD B vest worn over the utility shirt and trousers.

Figure B2b. Back view of the STD B vest worn over the utility shirt and trousers.

Figure B3a. Front view of the PASGT vest worn over the utility shirt and trousers.

Figure B3b. Back view of the PASGT vest worn over the utility shirt and trousers.

Figure B4a. Front view of the load-carrying equipment worn over the utility shirt and trousers.

Figure B4b. Back view of the load-carrying equipment worn over the utility shirt and trousers.

Figure B5a. Front view of the STD B vest and the load-carrying equipment worn over the utility shirt and trousers.

Figure B5b. Back view of the STD B vest and the load-carrying equipment worn over the utility shirt and trousers.

Figure B6a. Front view of the PASGT vest and the load-carrying equipment worn over the utility shirt and trousers.

Figure B6b. Back view of the PASGT vest and the load-carrying equipment worn over the utility shirt and trousers.

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APPENDIX C

Descriptions and Instructions for Task Battery

1. Ventral-Dorsal Head Flexion (reference 10).

a. Materials: Goniometer and straight-back chair.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on the right lateral surface of the head and is zeroed when the subject's head is forward and down in a ventral position. The shoulders remain against the back of the chair. The head is then tilted as far back as possible (dorsal position) and the displacement of the head from the zero position is read in degrees. Four trials are given with 15-sec intervals between trials.

c. Instructions to be read to the subject:

(1) Sit upright in the chair with your hands clasped behind the chair. Try not to move your chest or shoulders.

(2) When I tell you, bend your head as far down as possible without moving your chest or shoulders. Hold this position for five seconds. (Set the goniometer to zero.)

(3) Now bend your head as far back as possible without moving your shoulders or chest. Hold this position for five seconds.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

2. Head Rotation (reference 10).

a. Materials: Goniometer and straight-back chair.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The goniometer is placed on the cranial surface (top) of the head and is zeroed when the subject has rotated his head as far as possible to the left. It is read when the subject has rotated his head as far as possible to the right. Four readings are taken with 15-second intervals between trials.

c. Instructions to be read to the subject:

(1) Stand straight and then bend at the waist until your chest and head are parallel to the floor. Grab the seat of the chair to hold yourself that way.

(2) Turn your head to the left, and then hold it. (Set the goniometer to zero.) Now turn your head to the right and hold it.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

3. Standing Trunk Flexion (reference 10).

a. Materials: Box with vertical scale attached which is marked at .25-in. intervals.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Record to the nearest .25-in. the point on the vertical scale that the subject reaches and holds for 5 sec. Make four successive measurements with 15-sec intervals between trials. Be sure the knees do not bend.

c. Instructions to be read to the subject:

(1) You will stand on this box with your feet parallel, about four inches apart, and with your toes at the edge of the box facing the upright stick. Keep your knees stiff and do two preliminary toe touches. Then take a third toe touch. Keeping your hands together and sliding your palms down the outside surface of the board, hold the lowest point you can touch for a few seconds before you straighten up again.

(2) Are there any questions? (Correct the subjects if they are not following instructions.)

4. Sitting Trunk Flexion (reference 10).

a. Materials: Bench and horizontal scale marked at .25-in. intervals.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Record to the nearest .25-in. the point on the horizontal scale that the subject reaches and holds for 5 sec. Make four successive measurements with 15-sec intervals between trials. Be sure the knees do not bend.

c. Instructions to be read to the subject:

(1) You will sit on this bench with your knees stiff and your legs out in front of you.

(2) With your heels braced against the wall, bend forward twice. Then bend forward a third time, reaching as far forward as you can. Keep your knees stiff at all times. Hold the position for five seconds.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

5. Upper Arm Abduction (reference 11).

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right arm just above the elbow with the dial on the posterior side of the arm. Set the goniometer to zero. Be sure that the subject is standing with toes, abdomen, sternum and nose against the projecting corner of a wall. Watch for contact with the wall, extension of the back, arm rotation, elbow flexion, and movement out of the frontal plane. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with 15-sec intervals between trials.

c. Instructions to be read to the subject:

(1) Start facing the corner with toes, abdomen, sternum, and nose against the corner of the wall, arms hanging at your sides, palms facing in toward the body. (Set the goniometer to zero.)

(2) Raise both arms sideward and upward as far as possible while maintaining the contacts with the wall.

(3) Are there any questions? (Correct the subjects if they are not following the instructions.)

6. Upper Arm Forward Extension (reference 10).

a. Materials: Goniometer.

b. Instructions to the tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right arm just above the elbow with the dial on the lateral surface. Be sure that the subject is standing with his arm against his side, elbow stiff and the arm perpendicular to the floor. Set the goniometer to zero. Read the goniometer when the arm is raised as far forward and up as possible. The elbow is kept stiff and the arm parallel to the median plane. The trunk is maintained erect. There are four trials with 15-sec intervals between trials.

c. Instructions to be read to the subject:

(1) Stand facing the wall but not quite touching it. Your right shoulder and arm should be just past the edge of the doorway.

(2) Place your right arm against your side with the elbow stiff and the arm straight down. (Set goniometer to zero.)

(3) Now raise your entire arm forward and up as far as possible. Keep your elbow stiff and stand up straight.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

7. Upper Arm Backward Extension (reference 3).

a. Materials: Goniometer.

b. Instruction to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands erect with the back against a wall. The entire arm, elbow stiff, is rotated until the palm of the hand faces outward and the thumb points dorsally. The goniometer is placed on the right arm just above the elbow and is set to zero when the arm is perpendicular to the floor. The subject extends the entire arm backward as far as possible while keeping the elbow stiff and the palm out. Read the goniometer when the limit of motion is reached, when the elbow bends, or when the arm moves out of the medial plane. There are four trials with 15-sec intervals between trials.

c. Instructions to be read to the subject:

(1) Stand with your back to the wall. Your right shoulder and arm should be just past the edge of the doorway.

(2) Place your right arm against your side with the elbow stiff and the arm straight down. Rotate your arm until your palm faces outward. (Set the goniometer to zero.)

(3) Now raise your entire arm backward as far as possible. Keep your elbow stiff and your palm out.

(4) Are there any questions? (Correct the subjects if they are not following instructions.)

8. Upper Leg Abduction (reference 3).

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the posterior side of the leg. Be sure that the subject is standing erect, feet together, and facing an upright support. The subject grasps the support firmly with both hands. Set the goniometer to zero. Watch for bending of the trunk and leg rotation. The reading is taken at the point where a deviation occurs or no further movement is possible. Four trials are given with a 15-sec interval between trials.

c. Instructions to be read to the subject:

(1) Start facing this support and about one foot from it. Stand erect with your feet together and grasp the support with both hands. (Set the goniometer to zero.)

(2) Raise your right leg sideward and up as far as possible being careful not to bend your trunk or rotate your leg. Also, keep your knee stiff.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

9. Upper Leg Forward Extension (reference 8).

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the lateral surface. The subject stands erect with the back against a wall and the feet together. Set the goniometer to zero. Read the goniometer when the right leg is raised as far forward and up as possible. The knee is kept stiff and the back is kept against the wall. An upright support is grasped with the left hand to maintain balance. There are four trials with 15-sec intervals between trials.

c. Instructions to be read to the subject:

(1) Stand erect with your feet together and your back against this wall. Grasp the support with your left hand. (Set the goniometer to zero.)

(2) Raise your leg forward and up as far as possible. Keep your knees stiff and your back against the wall.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

10. Upper Leg Flexion (reference 3).

a. Materials: Goniometer.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Place the goniometer on the right leg just above the knee with the dial on the lateral surface. The subject stands erect with the back against a wall and feet together. Set the goniometer to zero. Read the goniometer when the right upper leg is raised as far up as possible. The right leg is allowed to bend freely at the knee. An upright support is grasped with the left hand to maintain balance. There are four trials with 15-sec intervals between trials.

c. Instructions to be read to the subject:

(1) Stand erect with your feet together and your back against this wall. Grasp the support with the left hand. (Set the goniometer to zero.)

(2) Raise your upper leg up as far as possible. Let your lower leg bend freely at the knee. Keep your left knee stiff and your back against the wall.

(3) Are there any questions? (Correct the subjects if they are not following instructions.)

11. Pursuit Rotor (reference 12).

a. Materials: A turntable, 26 cm in diameter, with a circular target disc, 1.25 cm in diameter, embedded in the turntable surface, and a stylus with a tip 0.4 cm in diameter. These components are located on top of a table.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject stands and holds the stylus in the preferred hand. While the turntable is revolving at 60 rev/min, the subject is to track the moving target by keeping the stylus in contact with it. The score is the total number of seconds during a 30-sec trial that the stylus is in contact with the target. Four trials are given with a 30-sec interval between trials.

c. Instructions to be read to the subject:

(1) Hold the stylus in your preferred hand. Place the tip of the stylus on the moving target and move the stylus in order to keep it in contact with the target.

(2) Your score is the total amount of time that you can keep the stylus on target during a 30-sec trial.

(3) Begin tracking the target. The trial will start when you make initial contact with the target.

(4) Are there any questions?

(5) Begin tracking.

12. Figure-8 Run and Duck (reference 13).

a. Materials: Two upright poles with adjustable supports for the 213.36-cm long crossbar.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Two uprights are placed 213.36 cm apart with the horizontal crossbar adjusted to the height of the subject's waist. The score is the time required for the subject to complete six Figure-8 runs of the course.

c. Instructions to be read to the subject:

(1) Start at the left of one of the uprights. On the signal "Go", run under the crossbar, around the far upright, back under the crossbar, and around the near upright. Run around the uprights in a Figure-8 pattern. Duck under the crossbar each time by bending at the waist, bending your knees only as necessary to complete the motion.

(2) Your score is the amount of time required to complete six Figure-8's.

(3) Are there any questions?

13. O'Connor Dexterity Test (reference 14).

a. Materials: Pegboard equipped with pins and located on a table. The pins are 2.5 cm long and 0.1 cm in diameter. Each hole in the pegboard is 0.5 cm in diameter.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The time required to place three pins in each of 20 holes is the subject's score. The subject stands to do the task and can use only one hand.

c. Instructions to be read to the subject:

(1) Begin with your preferred hand on the table alongside the board.

(2) On the "Go" signal, pick up as many as three pins with your preferred hand and place them in a hole on the board. Continue picking up and dropping the pins into the holes with your preferred hand until there are three pins in each hole.

(3) Your score is the time required to put three pins in every hole.

(4) Are there any questions? Ready? Go. (Correct the subjects if they are not following instructions.)

14. Bennett Hand Tool Dexterity Test (reference 15).

a. Materials: One adjustable wrench, two open-end wrenches of different sizes, one screwdriver, and two wooden uprights, 22.7 cm high and 35.6 cm apart, with three rows of holes. Two bolts are located in each row of one upright. The bolts in the top row are 7.2 cm long and 1.4 cm in diameter. Those in the middle row are 6.8 cm long and .7 cm in diameter. The bolts in the bottom row are 5.4 cm long and .5 cm in diameter. The heads of the bolts and the holes vary likewise in diameter. Each bolt is secured to the upright by two washers and a nut. The bolts in the upper rows have flat heads and those in the bottom row have slotted heads.

b. Instructions to the teater: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The subject's score is the time required to loosen and remove all the bolts, nuts, and washers from one upright and to relocate and tighten them on the other upright. The subject stands to do the task.

c. Instructions to be read to the subject:

(1) The idea of this test is to remove all six bolts from this upright and place them in corresponding rows on the other upright with the heads of the bolts on the inside. Use two tools to loosen each bolt and spin off the nut with your fingers. Loosen both nuts in a row before putting down your tools.

(2) First loosen the bolts in the top row using the adjustable wrench to hold the nut and the larger, open-end wrench to hold the head. Remove the bolts from the top row and put them down on the bench. Then loosen the bolts in the middle row using the adjustable wrench to hold the nut and the smaller, open-end wrench to hold the head. Remove the bolts and put them down. Finally, loosen the bolts in the bottom row using the adjustable wrench to hold the nut and the screwdriver to hold the head. As you remove these bolts, place them in the holes in the bottom row of the other upright.

(3) Use the appropriate tools to tighten the bolts in the bottom row after you have tightened them with your fingers. Then place the bolts in the middle row and tighten them and, finally, do the top bolts. In placing the bolts in the upright, make sure that the heads are on the inside. Your score is the time required to relocate six bolts.

(4) Are there any questions?

(5) Begin at the "Go" signal.

(6) Ready? Go. (Correct the subjects if they are not following instructions.)

15. Railwalking (reference 16).

a. Materials: A rail 365 cm long and 1.90 cm thick, marked at intervals of 1 cm.

b. Instructions to tester: Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: Record to the nearest 1 cm the distance walked before a foot touches the support of the rail or the floor. Walking must be heel to toe and the subjects must keep their hands grasped behind their backs.

c. Instructions to be read to the subject:

(1) Stand at this end of the board ready to begin walking. Start by placing one foot on the board so that the back of the foot is even with the end of the board. Then place your other foot in front of the first so that the heel touches the toe of the first foot. Walk as far as you can in this fashion, heel to toe. Grasp your hands behind your back for this test.

(2) Your score will be the distance to the end of the toe of the last foot that remained on the rail.

(3) Any questions? Begin.

16. Ball-Pipe Test (reference 11).

a. **Materials:** Steel balls 2.22 cm in diameter. A pipe 2.54 cm in internal diameter and 50.80 cm long is attached vertically to a wall with a net located below the bottom end of the pipe at least 91.44 cm from the floor. An electric counter is activated by a switch located in the pipe 25.40 cm from its top. The height of the pipe is varied according to the subject's height such that the top of the pipe is 14.50 cm above the top of the subject's head.

b. **Instructions to the tester:** Read the instructions to the subject. Read them word for word. Do not change or add to them.

Scoring: The number of times a steel ball is dropped through the pipe each 30 sec is recorded. The subject performs with the same hand continuously for 3 min. The subject is to drop and catch the ball with the same hand, but failure to catch the ball does not deduct from one's score.

c. **Instructions to be read to the subject:**

(1) Stand facing the pipe. You are to pick up a steel ball with your preferred hand and put it in the top of the pipe. Drop it into the pipe and attempt to catch it at the bottom with the same hand. Put the ball through the pipe as rapidly as you can. Your score is the number of times you put the ball through each 30 seconds. If you drop the ball, pick up the other ball in the net and continue immediately. The test lasts three minutes and you must use only one hand.

(2) Are there any questions?

(3) Begin at the "Go" signal.

(4) Ready? Go. (Correct the subjects if they are not following instructions.)

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APPENDIX D

Clothing and Personal Equipment

Performance Questionnaire

CLOTHING AND PERSONAL EQUIPMENT PERFORMANCE QUESTIONNAIRE

Name: _____ Clothing: _____

Section I. Movement and Task Performance

1. Choose the three movements, or the three tasks, MOST IMPAIRED by the present experimental condition. Assign a rank of 1 to the most impaired, a rank of 2 to the second, and a rank of 3 to the third most impaired. Respond first to the movements and later to the tasks.

Movements		Tasks	
Head Flexion, Ventral-Dorsal	_____	Pursuit Rotor	_____
Head Rotation	_____	Figure-8 Run and Duck	_____
Standing Trunk Flexion	_____	O'Connor Finger Dexterity	_____
Sitting Trunk Flexion	_____	Bennett Hand Tool	_____
Upper Arm Abduction	_____	Railwalking	_____
Upper Arm, Forward Extension	_____	Ball-Pipe	_____
Upper Arm, Backward Extension	_____		
Upper Leg Abduction	_____		
Upper Leg, Forward Extension	_____		
Upper Leg Flexion	_____		

2. Choose the five design characteristics which were MOST IMPORTANT IN INTERFERING with your movements OR IMPAIRING your task performance. Assign ranks from 1 through 5 to the first through the fifth most important source of interference or impairment. Respond first to the movements and later to the tasks.

Design Characteristics	Movements	Tasks
Armhole opening size	_____	_____
Bulk	_____	_____
Chest fit	_____	_____
Chest flexibility	_____	_____
Collar fit	_____	_____
Collar flexibility	_____	_____
Protruding parts	_____	_____
Shoulder width	_____	_____
Shoulder flexibility	_____	_____
Stability	_____	_____
Ventilation	_____	_____
Waist fit	_____	_____
Waist flexibility	_____	_____
Weight	_____	_____

Section II. Importance of Design Characteristics

1. Rate each of the design characteristics listed below to show how important they were to you in INTERFERING with the movements and tasks you have performed.

Design Characteristics	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERABLE IMPORTANCE	OF EXTREME IMPORTANCE
a. Armhole opening size					
b. Bulk					
c. Chest fit					
d. Chest flexibility					
e. Collar fit					
f. Collar flexibility					
g. Protruding parts					
h. Shoulder width					
i. Shoulder flexibility					
j. Stability					
k. Ventilation					
l. Waist fit					
m. Waist flexibility					
n. Weight					

Comments (additional characteristics, etc.):

2. Rate each of the design characteristics listed below to show how important they were in HELPING you to do well on the movements and tasks you have performed.

Design Characteristics	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERABLE IMPORTANCE	OF EXTREME IMPORTANCE
a. Armhole opening size					
b. Bulk					
c. Chest fit					
d. Chest flexibility					
e. Collar fit					
f. Collar flexibility					
g. Protruding parts					
h. Shoulder width					
i. Shoulder flexibility					
j. Stability					
k. Ventilation					
l. Waist fit					
m. Waist flexibility					
n. Weight					

Comments (additional characteristics, etc.):

3. Rate each of the problems listed below to show how important they were in INTERFERING with OR IMPAIRING your performance on the movements and tasks.

Problems	OF NO IMPORTANCE	OF LITTLE IMPORTANCE	OF MODERATE IMPORTANCE	OF CONSIDERABLE IMPORTANCE	OF EXTREME IMPORTANCE
a. Bulky					
b. Chaffing					
c. Digging in					
d. Heavy					
e. Hot					
f. Loose					
g. Obstructions					
h. Pressure					
i. Pinching					
j. Slipping					
k. Tight					
l. Unbalanced					

Comments (additional problems, etc):

Section III. Preference

Indicate your opinion, whether neutral, positive, or negative, on each of the following dimensions. Circle the appropriate vertical line.

While performing the movements and tasks, I found the clothing and equipment to be:

	extremely −3	very −2	somewhat −1	neutral 0	somewhat +1	very +2	extremely +3	
1.								uncomfortable / comfortable
2.								inflexible / flexible
3.								poorly ventilated / well ventilated
4.								heavy / light
5.								poorly balanced / well balanced
6.								poorly fitted / well fitted
7.								riding up / staying down
8.								binding / free moving

In general, my attitude toward the clothing and personal equipment was:

	extremely −3	very −2	somewhat −1	neutral 0	somewhat +1	very +2	extremely +3	
9.								dislike / like